MODIS Team Member - Semi-annual Report

Marine Optical Characterizations
December 2001

Dennis K Clark
NOAA/NESDIS

SUMMARY

Since the launch of NASA's TERRA satellite, the Marine Optical Characterization Experiment (MOCE) Team has continued to acquire and provide at-sea observations for MODIS initialization and calibration tasks. The Marine Optical Buoy (MOBY) system has been acquiring optical and basic meteorological observations coincident with TERRA's overpasses in support of the Moderate Resolution Imaging Spectrometer's (MODIS) ocean color mission. During this period, the team conducted four field campaigns in Hawaii in support of the MOBY project. These cruises, designated MOBY-L70 through MOBY-L73, serviced the MOBY217 and MOBY218 systems. A Marine Optical Characterization Experiment (MOCE-9) was carried out in Hawaii November - December 2001 to provide additional initialization data for the MODIS Side A electronics configuration. Additionally, the team is continuing to provide the SeaWiFS Project observations for their validation and long-term calibration tasks and to collaborate with NIST personnel in conducting stray-light characterizations of the MOBY/MOCE optical systems. A summary of the team activities during this reporting period is shown in Figure 1.

FIELD OPERATIONS

During this reporting period, MOCE team members and professional divers conducted three calibration excursions via Hawaiian Rafting Adventures (HRA) chartered dive boat to perform diver calibrations (MOBY-L70, MOBY-L71, and MOBY-L73).

During MOBY-L70 (July 3 - 6), MOBY, Meteorological station (LMOB), and CIMEL maintenance was performed. During this trip up to three large oceanic white tip sharks were present almost constantly and became increasingly aggressive each day. The second diver's primary responsibility was to watch the back of the working diver. In fact, during the afternoon of the third day, one of the divers had to use a boat pole to dissuade one shark that approached the divers too closely. Although sharks have been encountered at the MOBY site in the past, they have never been quite this persistent or troublesome. If this behavior continues, procedural changes may have to be made to ensure of the safety of the science divers. Figure 2 depicts white tip shark cruising at the MOBY site.

During the MOBY-L71 (August 24 - 26) cruise, MOBY and CIMEL maintenance was performed. Our personnel performed before-cleaning diver reference lamp measurements on MOBY217 and collected HPLC seawater samples. MOBY optical collectors were cleaned and post-cleaning diver lamp scans were performed the next day of the trip along with collection of additional HPLC samples. It was noted that the top arm of MOBY was bent downwards (Figure 3). Upon closer examination of the MOBY data set, it was determined that this top-arm anomaly occurred on August 6, 2001. Damage to the arm on MOBY217 was clearly due to contact with a boat. We are looking into ways to notify the boating public of the submerged hazard near the buoy. We may make mechanical modifications to add support to the upper arm and to provide better visual indicators to notify boaters of the arm's presence just below the surface.

MOBY-L73 occurred in October 2001. Our personnel flew to Maui on the 23rd to setup the equipment for the boat trip to Lanai on the 24th, where before-cleaning diver scans on MOBY218 were performed. Optics were cleaned on the 25th and after-cleaning scans performed. Additionally, HPLC water samples were filtered and preserved during both outings.

The MOBY-L72 recovery and replacement cruise occurred August 24 - 26, 2001 aboard the R/V Ka'imikai-o-Kanaloa. MOBY218 was loaded aboard ship early the morning of September 24 and deployed late that afternoon in the lee of Lanai - adverse wind conditions prevented deployment operations at the MOBY mooring site. The morning of September 25 was also too windy to exchange MOBY 217 and 218 but both instruments acquired optical profiles under clear skies at the mooring site concurrent with a ship-deployed Fiber Optic System (FOS) profile. Calm winds that afternoon allowed MOBY218 to be moored, MOBY217 to be put under tow, and its flopper-stoppers retrieved. MOBY217 was retrieved in the morning of September 26 in the lee of Lanai. Diver reference lamp scans and a Wide Angle Radiance System (WARS) deployment were performed, while the rest of the science crew made bio-optical measurements concurrent with the MODIS overpass. The University of Hawaii small boat R/V Klaus Wyrtki was outfitted for day trips out of Snug Harbor, Oahu (Figure 4). Some effort was required to convert the Klaus Wyrtki for MOCE day cruise use. The ship's AC power was not adequate for our needs. We built a power system based on a Fisher-Panda marine generator to provide 'clean' power to the instruments and computer acquisition systems. Air conditioning systems were built and installed to cool the hot compartments used to house the equipment. Three day trips were conducted to get acquainted with small boat type operations.

The MOCE-9 MODIS calibration and validation cruise occurred November 27- December 14, 2001 aboard the small R/V Klaus Wyrtki. The boat carried 9 to 12 people each day trip. The usual schedule was to start steaming around 7 AM for 2 to 3 hours for the clear spot (no clouds) to carry out the experiments. Seven stations were occupied during both MODIS and SeaWiFS overpasses. MICROPRO, FOS, MOS, and RADS measurements were conducted. Figure 5 depicts the FOS instrument deployment. It was hang on the outrigger and lowered by the length marker rope to determine the depth of deployment. The FOS electronic system was upgraded to activate the depth and orientation (tilt) sensor.

A new acquisition and control PC laptop system was purchased to replace the aging VAX system for the MOS/SIS instruments. This system was successfully used during the MOCE-9 cruise aboard the R/V Klaus Wyrtki, whose cramped quarters made it nearly impossible to deploy the VAX acquisition system.

During the cruise we worked with Dr. Ken Voss from the University of Miami to test and operate the next generation of angular distribution camera, the NuRADS. This prototype lightweight radiance distribution camera was developed to replace his old RADS camera and his group is currently building one for our group.

Water samples were collected and filtered for fluorometric and HPLC analyses. We worked on obtaining chlorophyll *a* standard, calibrating 2 fluorometers, and running all fluorometric pigments on 2 different project fluorometers for comparison (Figure 6). Given a large enough range (here up to ~5 mg l^{-1} chla), the MOBY and Mill Creek fluorometers are linear and 1:1 within a 2% error. Previous comparisons with less of a dynamic range in chlorophyll concentrations showed offsets of up to 11%. 46 colored dissolve organic material (CDOM) samples were collected. In anticipation of the new World Precision laser absorption meter becoming fully operational in the near future, CDOM samples were analyzed on the HP8452A spectrophotometer twice. One spectrum was obtained using the traditional Millipore Sterivex-GV (0.22 um) filter and the other was obtained using the Whatman Anotop (0.1 um) filter. Comparison between the two spectra might allow for later correlation between past samples analyzed by the HP8452 and future samples by the laser absorption meter. Initial comparison of clean water spectra showed that the Anotop filter has a residue on it which may lead to high CDOM measurements if the filter is not rinsed prior to analysis. Data analysis and processing for the entire MOCE-9 CDOM data set is nearly complete.

RADIOMETRIC STANDARDS & RADIOMETERS

Team personnel stationed at the NOAA operations facility at Snug Harbor, Hawaii continued maintenance of our NIST-traceable radiometric standards and performed calibrations of our radiometers. We took delivery in April of hardware and software to upgrade our precision current supply system for 1000 Watt Irradiance FEL standards. We purchased two Agilent 3497 Data Acquisition / Switch Units with reed-relay multiplexers, two HP/Agilent 6030A DC power dupplies, one L & N 4361 Precision Shunt from Process Instruments Inc., and a PCMCIA-GPIB card and LabView software from National Instruments. This new system will be in accord with most- recent NIST practices. We are modifying LabView software developed at NIST to control the new power supply system. The MLML OL425 radiance standard was returned to Optronic Laboratories after MOBY217 post-deployment calibrations in November with 47.6 hours use, was post-calibrated (lamp #2) by OL on December 10th, and was re-lamped (lamp #3) and calibrated on December 19th. We received the OL425 in Hawaii on the 27th of December. At the end of December, the OL420 radiance source had 27.5 hours use since its February 2000 lamp #6 calibration, the F454 FEL irradiance standard had 35.1 hours use since its July 1998 NIST calibration, F454 had 9.5 hours on a February 2001 calibration, and F471 has not yet seen service since it's February 2001 calibrations. The Standard Lamp Monitors, SLMs, were pending return to NIST to repeat the irradiance characterization via the SIRCUS facility.

Radiometric calibrations during the reporting period included:

1. Post-deployment calibration of MOBY216 and MOS204cfg05 in July 2001
2. Pre-deployment MOBY218/MOS204cfg06 and NIST-2001-03 NIST visSR in August 2001

3. Pre-deployment MOBY218/MOS205cfg05; Pre-MOBY-L72 MOS202cfg08 and SIS101cfg04 in September 2001
4. FOS, the NIST VisSR, and Post-deployment MOBY217 in October 2001
5. Post-deployment MOBY217/MOS205cfg06 during the fourth NIST stray light experiment - NIST-2001-04 in November 2001
6. Pre- and Post-MOCE9 FOS in December 2001

Detailed listing of calibrations and maintenance for each standard and instrument are provided in Appendix 1.

STRAY LIGHT CHARACTERIZATION

In April 2001, Mark Yarbrough and Mike Feinholz traveled to Gaithersburg, MD to work with Drs. Steve Brown, Keith Lykke, and Carol Johnson at NIST. These experiments are annotated as NIST-2001-02. A characterization of stray light in the MOS202 radiometer was accomplished and a preliminary correction procedure developed for up-welling radiance spectra. The correction algorithm addresses the discrepancy in the MOS spectrograph's overlap region. Stray light is generated by forward-scattered (haze) and isotropic (diffuse) radiation from the single holographic grating plus any light scattered from other optical elements. This leads to MOS "out-of-band" signal. The NIST Spectral Irradiance and Radiance Calibration facility using Uniform Sources (SIRCUS), which produces spatially uniform, monochromatic, broadly tunable radiance was used to accurately determine "in-band" and "out-of-band" components in measured MOS signal. The wavelength range 362 - 936 nm was measured at 2 - 5 nm intervals to characterize the entire spectral range of MOS responsivity. High resolution scans at 0.2 nm intervals were measured over several ranges: 430 - 440, 555 - 565, 760 - 770, 860 - 865 nm. High-resolution scans defined the MOS blue and red spectrographs' in-band profile, which will be used in the Stray Light Correction Algorithm. Additionally, MOS viewed the NIST OL420 sphere with and without colored glass filters to establish test conditions for correcting broadband blue-rich and green-rich spectra via a calibration response established with a red-rich source. Finally, a TT7 temperature characterization was attempted at blue and red wavelengths in and out of the overlap region. Over eleven hundred MOS scan sets were acquired during three weeks of measurements at NIST (see Appendix 1 for MOS202 calibration file listing).

A preliminary MOS Stray Light Correction Algorithm was developed to separate in-band and out-of-band components from MOS measured signal at each CCD pixel. This correction is applied to both responsivity measurements of a calibrated radiance source and in-water upwelled radiance measurements. High-resolution SIRCUS laser scans were inverted and fit to a Lorenzian function to produce the SSF, or slit scattering function, for both blue and red spectrographs. Second order reflections observed in the MOS spectrographs were also modeled and included in the SSF. Removing the in-band portion yields an out-of band SSF. The out-of-band SSF is convolved with uncorrected response or signal, and the integral estimates the stray light component at each pixel. Subtracting the stray light gives "corrected" values. Corrected values are then used as input and the procedure is iterated until a steady state solution is reached. The validity of the algorithm was checked by applying uncorrected and corrected responsivity to measurements of the NIST Colored Source and comparing to NIST- determined source radiance. Preliminary estimates indicate corrected MOS Lu's are increased 3% and 6% at 412 nm. A NIST/NOAA/MLML poster outlining this work was presented at the 2001 Ocean Color Research Team Meeting in San Diego, California in May 2001.

NIST researchers Johnson and Brown returned to Hawaii in August to execute further characterizations on MOS204cfg06, (Pre-Deployment) MOBY218, SIS101cfg04, and FOS. These experiments were termed NIST-2001-03. The NIST "Traveling" SIRCUS and Colored Source were successfully operated in the calibration hut and in the MOBY tent. X-SIRCUS lasers remained in the calibration hut and the fiber optic was cabled to an NPR-II integrating sphere in the tent. X-SIRCUS was used to determine in-band responsivities for both blue and red spectrographs in MOS204 and for the top and middle arms of MOBY218; out-of-band was also determined for MOBY surface irradiance. Additionally, NIST brought four HeNe lasers, one diode laser, and an air-cooled Argon-Ion laser for out-of-band responsivity / reflection peak modeling measurements. The NIST OL420 Colored Source and Visible Spectroradiometer, VisSR, were operated in conjunction with the MLML OL425 and MOBY Lu Top to provide an algorithm-validation data base. The Stray Light Correction, SLC, algorithm for the profiling MOS202 was evaluated on MOCE-5 data sets, confirming that the blue/red overlap discrepancy was caused by stray light in both spectrographs. SIS and FOS data were collected, and the first FOS stray light correction algorithm was applied to the FOS data. SIS corrections will begin in the near future. Improvements were suggested for the MOS/MOBY SLC algorithm, a 440 nm diode laser was ordered, and plans for the October / MOBY217 trip were developed.

The last stray light experiment of 2001 in Hawaii was NIST-2001-04 from 1 - 16 October. The VisSR, employing an updated PMT preamplifier, was calibrated via the MLML OL425 and viewed the NIST OL420 Colored Source. Steve Brown and Carol Johnson succeeded in doubling the Ti:Sapphire laser for blue stray light out-of band measurements. Modeling work continued on the MOS202 profiler with the assistance of Stephanie Flora. FOS calibration via X-SIRCUS was completed and SLC algorithm development begun. Post-deployment MOBY-217 Lu Bot, Mid, and Top sensors were calibrated via X-SIRCUS R6G and Ti:S, Discrete Lasers (Ar-Ion, HeNe, and diode lasers), and the Colored Source which were left in Hawaii for our personnel to run on MOS205cfg06 after it is removed from MOBY217. Plans were refined for the next NIST visit to MOBY in January 2002. A detailed NIST-2001-04 trip report is provided in Appendix 2 Carol Johnson of NIST gave an invited talk titled "Stray Light Characterization for MOBY"at the AGU meeting in San Francisco , California in December 2001 (Appendix 3).

FOS

The instrument development portion of the system was completed. The final bit of work was to provide access to the analog systems of the instrument. This required the installation of serial line drivers for the compass module and controller, integration of a controller and 16-bit A/D card to digitize the pressure and temperature sensors. These data can be collected via terminal emulator during a cast and merged with the optical data during post-processing. It is possible to acquire this information in real time with the optical data, but an integrated acquisition program is required. The data processing software for the FOS was completed. The software allows the user to create system response files, dark scan files, process and error check the data, and calculate derived products. The Graphical User Interfaces (GUI's) allow users with limited MATLAB experience to easily and interactively check the data. Users with minimal experience with MATLAB have given the processing software high praise. Non-GUI functions process the data following MLML radiometric protocols. In addition to processing the data, HTML pages are created automatically, allowing the user to view the processed data easily. FOS data were stray light corrected for the first time with promising results. However, some adjustments still need to be made before the corrections are complete.

CIMEL SERVICE

The Lanai CIMEL site has operated well for the past year. The system is now due for replacement and re-calibration. We are working with Aeronet to coordinate the instrument replacement. We continue to service the instrument when possible as a part of the regular MOBY calibration work. The Coconut Island site has worked well except for a malfunctioning GOES transmitter unit, which caused the loss of most of November's data. This instrument will be moved to the Lanai site when the current Lanai instrument is returned to NASA for calibration. This instrument also receives regular monthly service.

MOBY WEATHER STATION

The work on fabrication and initial testing of the second Mooring Weather System LMOB202 is completed. The second station will be installed January 2002 in conjunction with the annual replacement of the mooring buoy. This version of the weather system will be similar to the system currently collecting data, LMOB201, with the exception of an additional sensor being incorporated into the data stream. A WETLabs C-Star transmissometer will be added to the underwater instruments to retard biofouling of the optical and the conductivity measurements. A problem encountered with LMOB201 occurred in middle of September where the charging system had failed to charge the batteries that supply power to the data logger. The battery pack/charge controller was removed from the buoy well and repaired. The two battery charge controllers were replaced, diodes were replaced to prevent reverse current flow and a bulkhead connector that had failed on the well cover was replaced. The package was reinstalled and the system continued to collect and transmit the weather data.

MICROPRO

The original SPMR was returned to Satlantic in October as partial payment for the upgraded MICROPRO system. This system continues to have communication glitches, which result in minor data loss during the profiles. These data issues are addressed in post-processing and do not degrade data quality. The small size of this system greatly eases launch and recovery activities. MICROPRO processing software will continue to be modified when required and as time permits.

DATA PROCESSING

Most of our effort has been spent monitoring the progress in the evolution in MODIS Ocean color products from Beta to Provisional to Validated. We continue to analyze global images and local images over Hawaii that are produced by MODAPS and by the University of Miami. The University of Miami is developing a new code version addressing problems arising from match-ups with our ground-truth data and validations from all MODIS team PIs. The dominant problem identified in the processing code during the past six months was that the earth-sun distance correction in L_t had been applied twice and therefore all previously processed data has a seasonally dependent error in the estimates of water leaving radiance. This error naturally propagates in all higher level products. As a result of this error in the MODAPS processing code, all our efforts over the past six months have been concentrating on analyzing versions of Miami's data.

On June 15, 2001, the MODIS sensor was shut down, and was restarted in July 2001 using internal Side A electronics. As a result, Miami was required to develop yet another validation and calibration processing scheme that maintains consistency between Side A electronics utilized prior to October 2000, Side B electronics utilized between October 2000 and June 2001, and again data produced using Side A electronics from July 2001 until present. In the fall of 2001, University of Miami personnel produced a version 3.4 code. That utilizes the correct earth-sun distance corrections, the calibrations that minimize MOBY time series - MODIS bias throughout the entire sampling period by normalization with MOBY data, mirror-side and cross-scan corrections derived from MOBY time-series data, and updated polarization corrections. As a result of this effort, they have reduced response versus scan angle differences within 40 degrees of nadir, reduced striping by adjusting detector gain settings and minimizing mirror side differences, reduced digitizer noise, and have revised polarization and sun glint corrections.

In December 2001, Miami released the Hawaii time- series granules and selected global images from several months in 2001. Even though refinement and upgrades in the code are expected in these provisional products, this data release allowed MODIS Ocean Team PIs the chance to validate individual products derived from the water-leaving radiance data. Once validated, final-processing codes will be forwarded to MODAPS in early 2002. Our group is currently providing five product algorithms. Chlor_MODIS is HPLC derived chlorophyll *a* concentrations, CZCS_pigment is fluorometrically derived chlorophyll *a* concentrations, Pigment_cl_total is total HPLC derived phytoplankton pigment concentrations, K_490 is the diffuse attenuation coefficient at 490 nm, and susp_solid_conc is the suspended solids concentration. Example images around the Hawaiian Islands processed with the latest Miami code for each product are given in Figures 7 to 11. We are continuing to validate these products produced by the University of Miami by comparisons to SeaWiFS data, monitoring between granule consistencies in global images and using ground truth data collected near Hawaii.

In order to test the sensitivity of primary productivity models to errors associated with remotely sensed chlorophyll *a* measurements, the absorption-based and P^b_{opt}-based models are being used.

In these simulations, models are run varying chlorophyll *a* concentrations while all other input parameters are held constant.

MOBY

MOBY continues to acquire and transmit two files per day, coincident with SeaWiFS and MODIS overpass times. MLML personnel process these files and make the data available on our MOBY home page the day after transmission. Both files are weighted to MODIS and SeaWiFS bands. This includes the MODIS total and in-band weighted data. These data are now available on the MOBY web site.

MLML personnel have completed rewriting all of the MOBY processing software. The new software is more flexible and the data files are organized more efficiently. During the MOCE-9 field experiment, Stephanie Flora finished writing the MATLAB programs required to stray light correct MOBY data. The stray light corrections were applied using a second generation model derived by Steve Brown and Carol Johnson of NIST. The MOBY algorithm was slightly different from the MOS algorithm and required the same careful programming. The MOBY stray light corrections had another added problem of keeping track of which stray light correction algorithm and coefficients were used to correct MOBY data. Another set of programs were written to create a stray light correction history for each MOBY deployment file and system response file. SeaWiFS MOBY match-up calibration data sets for deployments 3, 5, 7, 9, 11, 13, 15, and 17 were stray light corrected and sent to Gene Eplee (NASA). Future refinements of this model in all probability will not significantly change the results.

MOS/SIS

Mike Feinholz continues to process data from instrument calibrations and from shipboard MOS and SIS profiles using MATLAB programs customized at MLML. Three profiles were performed during 2 time-series solar-elevation experiments during MOBY-L69 in June, one during L-72 in September, and five during MOCE-9 in November-December. Profiles are typically coincident with MOBY profiles and/or SeaWiFS and MODIS observations. MOS water-leaving radiances are convolved with SeaWiFS and MODIS spectral band responses for integration with our bio-optical data base (see Appendix 4 for a MOS station summary).

PIGMENTS

A change in Chlorophyll *a* calculation is being discussed. Instead of using a varying response factor from the Chelsea fluorometer, a cruise average response factor will be used. This should keep the derived Chlorophyll product from being noisy from track-line to track-line. A new MATLAB program is being written to do the pigment data processing, incorporating the new response factor technique. Because of the change in pigment derivation, all MOCE cruise pigment data are being reprocessed. This will obviously take some time to finish.

PUBLICATIONS AND MEETINGS

Dennis Clark attended a MODIS Team Meeting in Washington, DC, December 17-19, 2001.

Rachel Kay completed work on her Master's thesis for Moss Landing Marine Laboratories and California State University Hayward entitled: Seasonal Chlorophyll Variability off Baja California from SeaWiFS Satellite Imagery.

MOBY CONTRACTS

Hawaiian Rafting Adventures received a new 1 year contract in October. The total amount of the contract is $48,000.

The University of Hawaii Marine Center Shore Support contract was extended by 6 months in December. That contract is now set for renewal on July 31, 2002.

Dr. Christopher Kinkade officially started as a post-doctoral fellow at the Cooperative Institute for Research in the Atmosphere at Colorado State University. While employed in this capacity, Dr. Kinkade is a visiting scientist to NOAA /NESDIS at Camp Springs, MD.

MOCE Team Activities

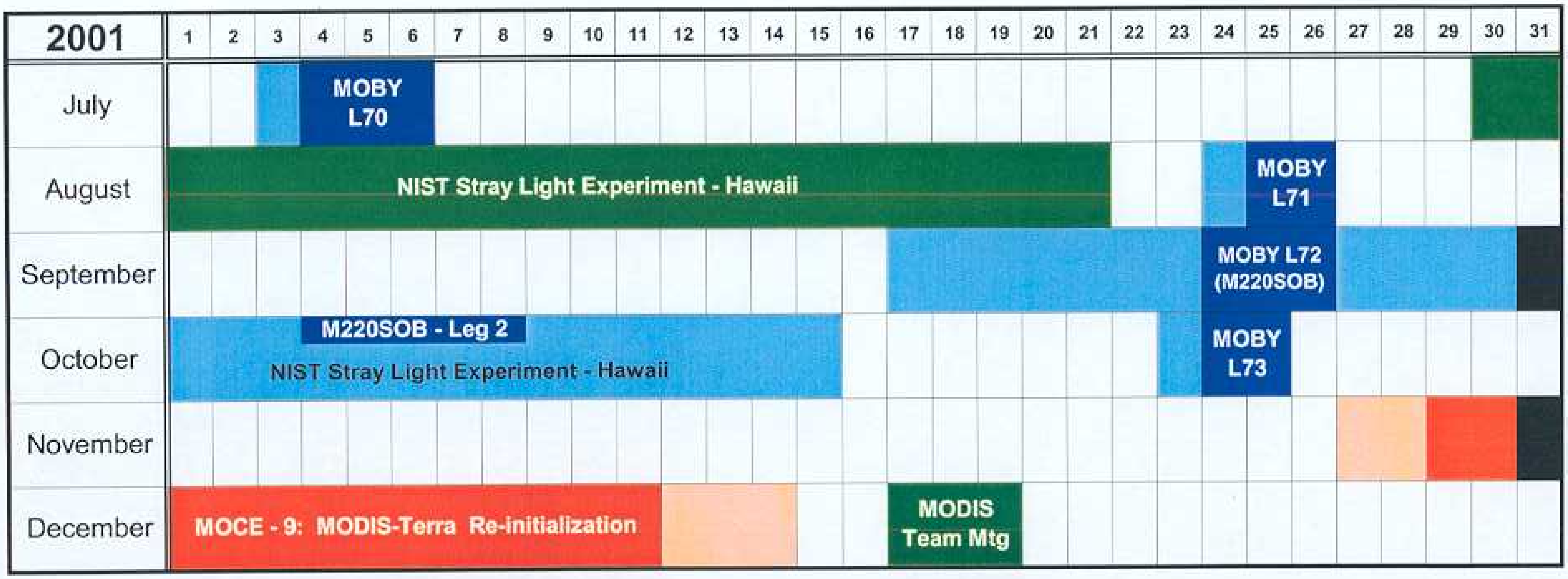


Figure 1

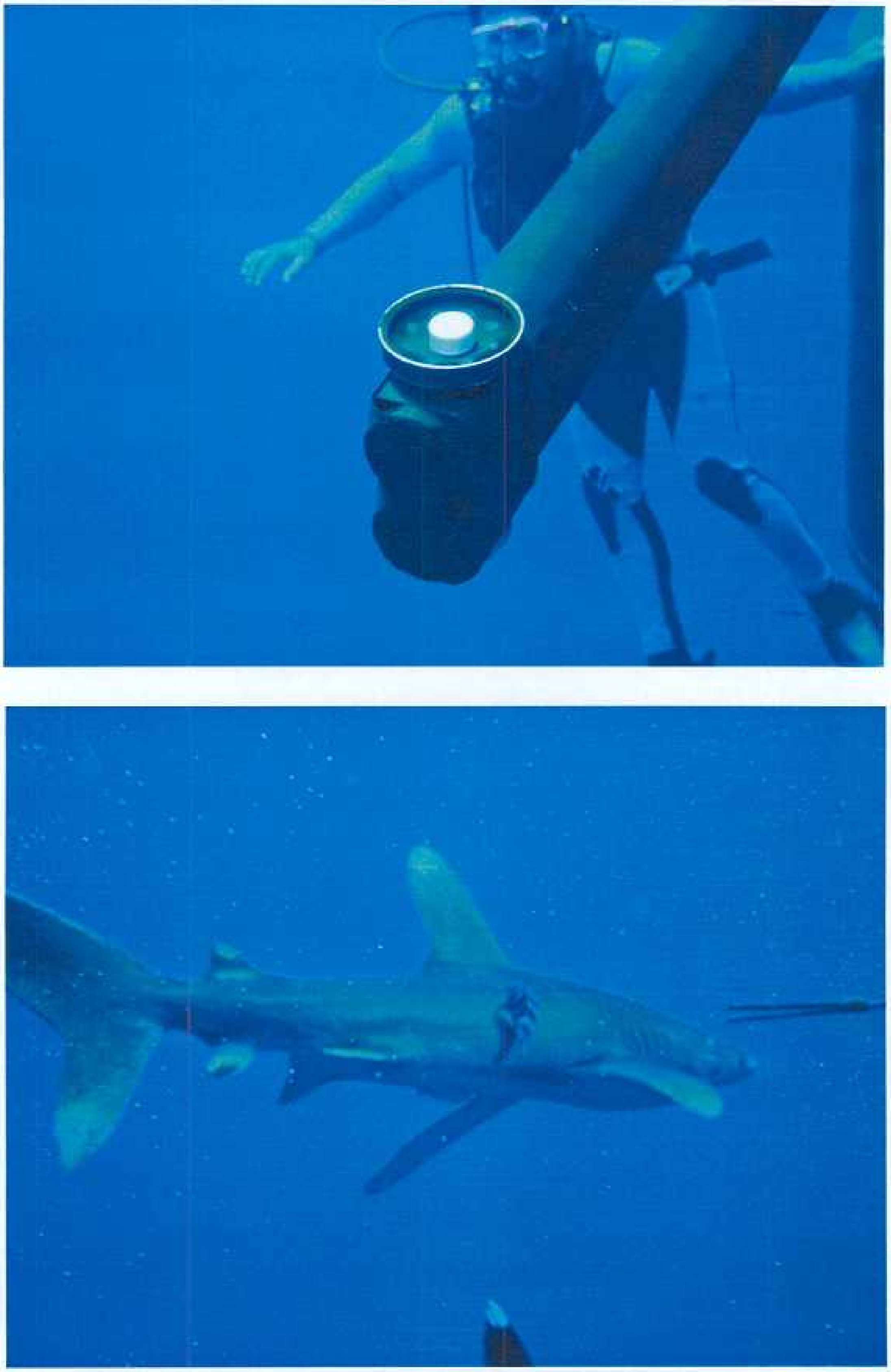


Figure 2

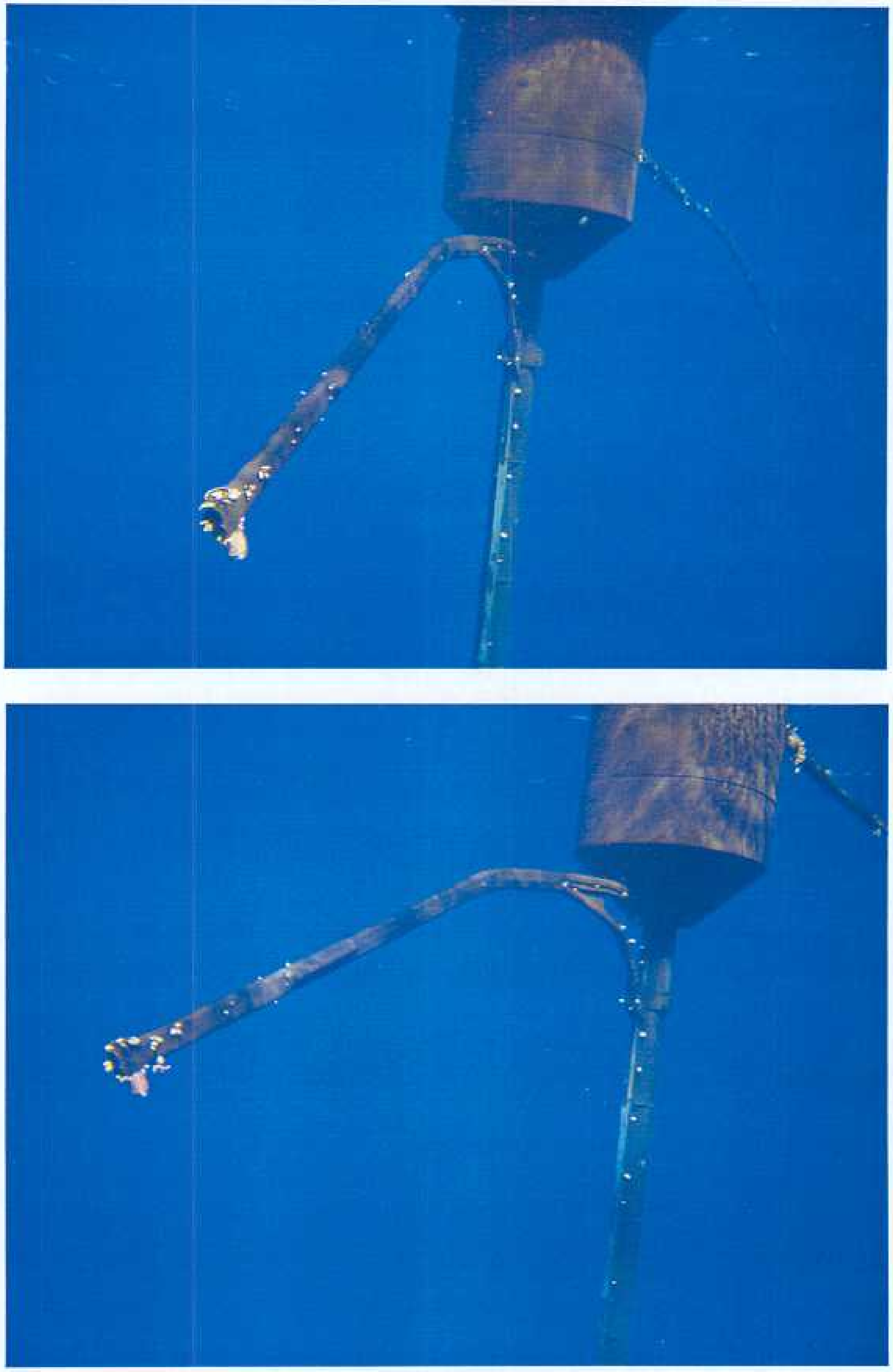


Figure 3

Figure 4

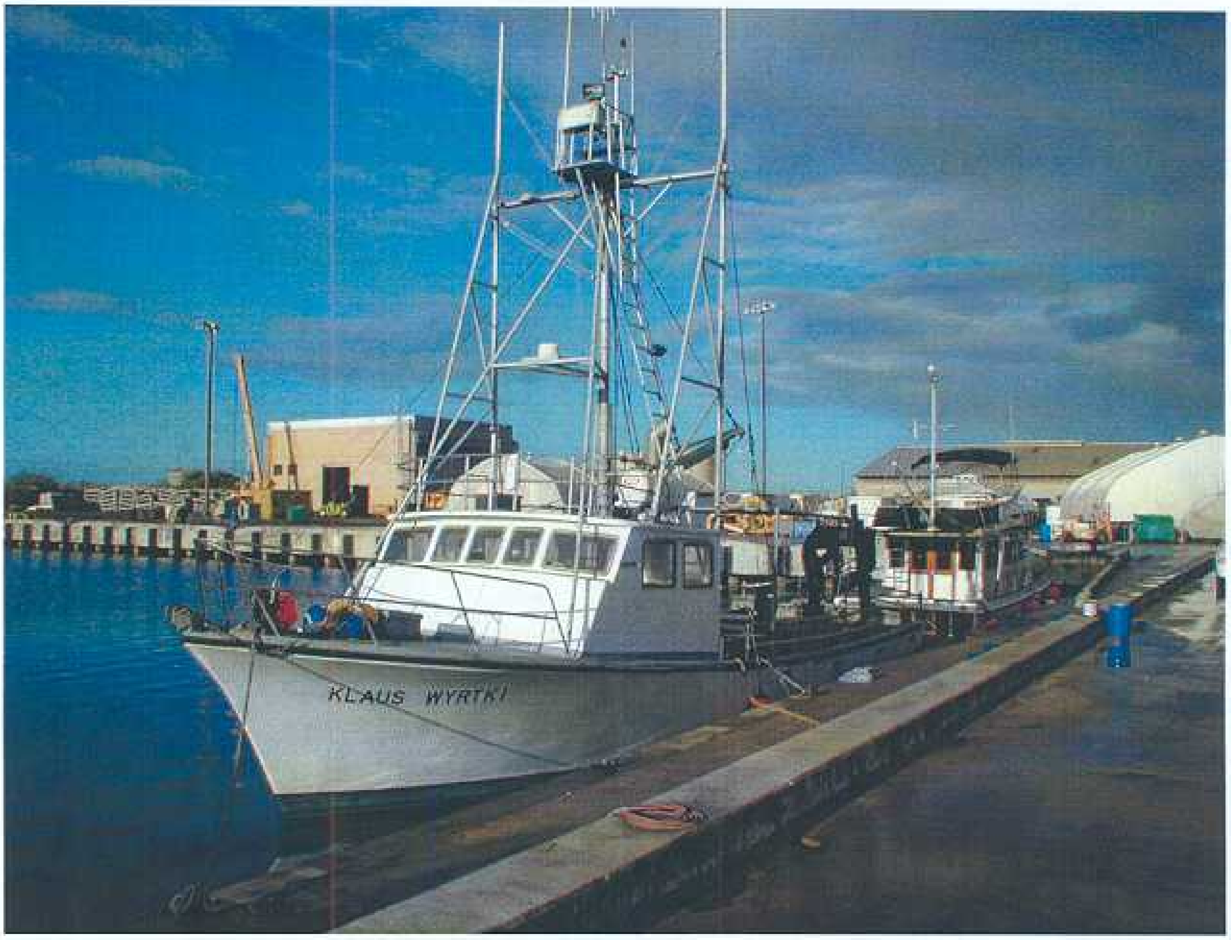


Figure 5

Figure 6: MOCE-9
MOBY vs. Mill Creek Fluorometrics

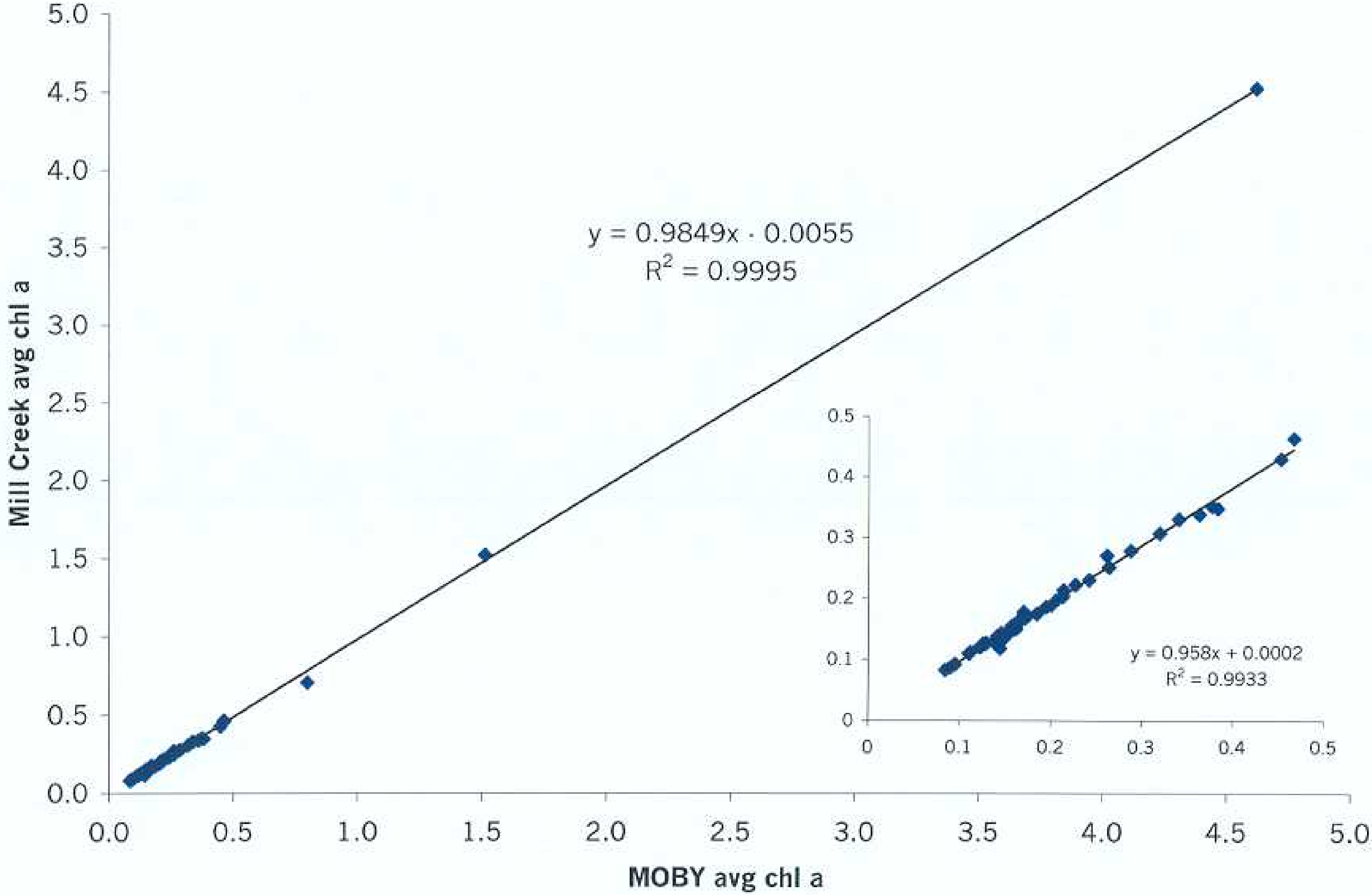
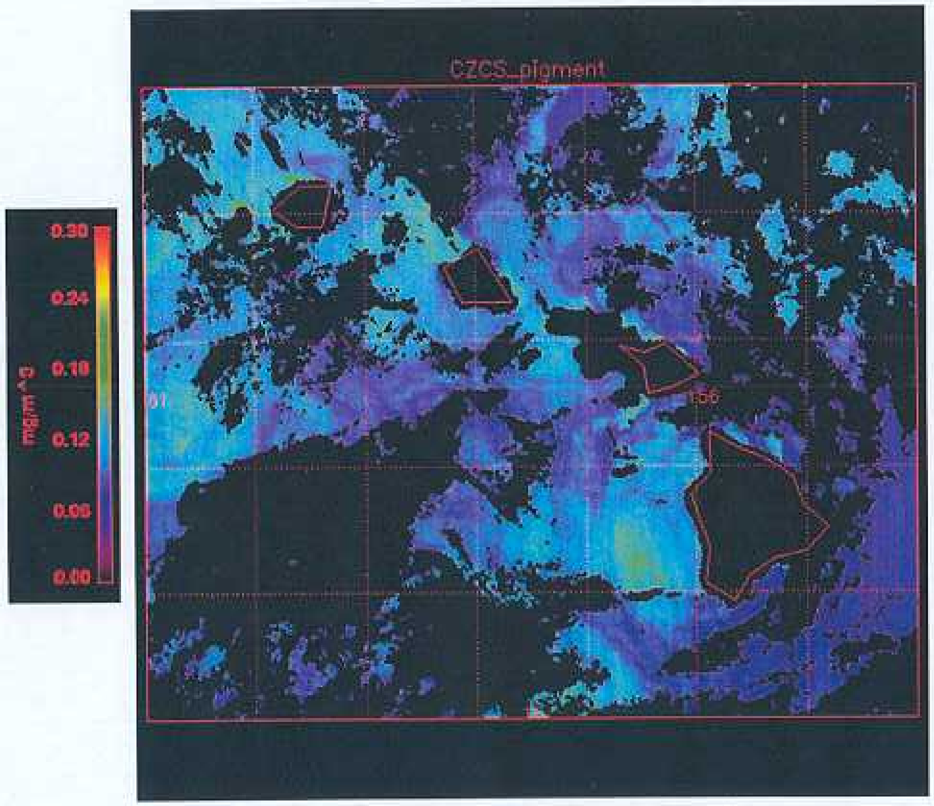
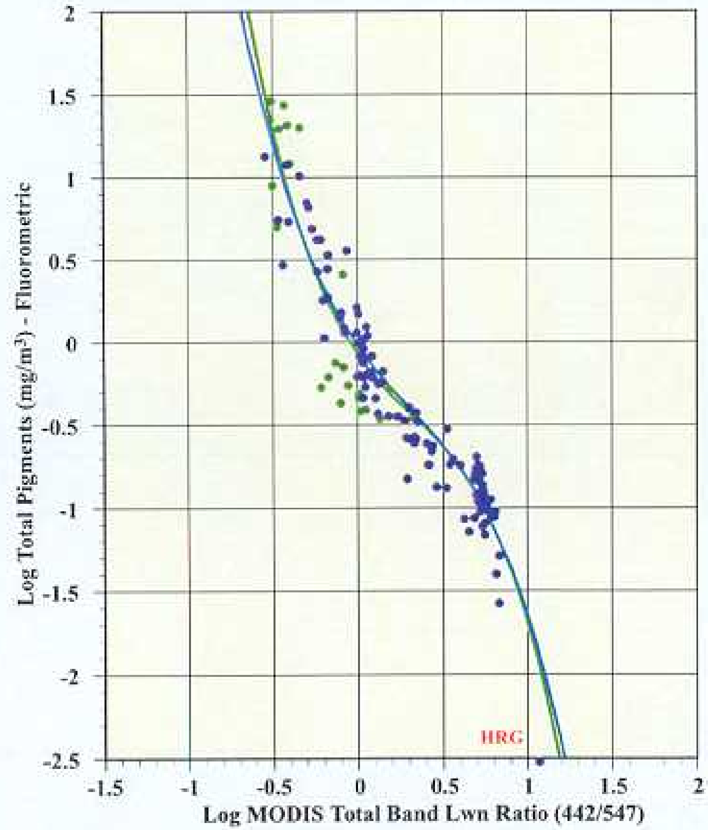


Figure 7. Product Number - MOD 19 Parameter 13, CZCS_pigment Day 345, 2000

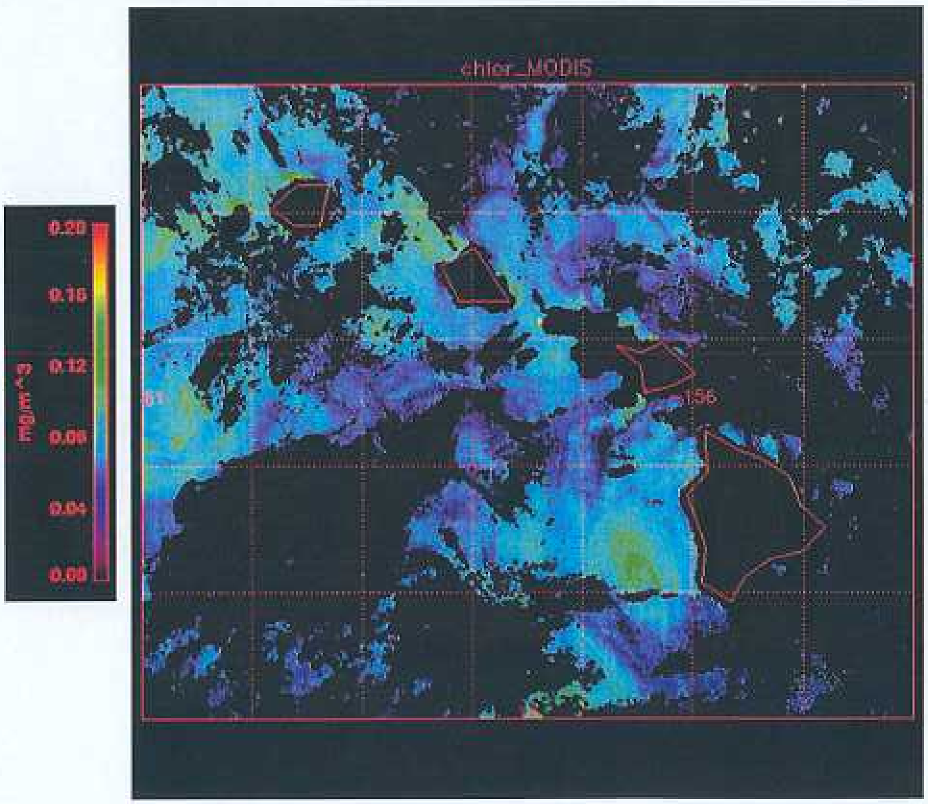


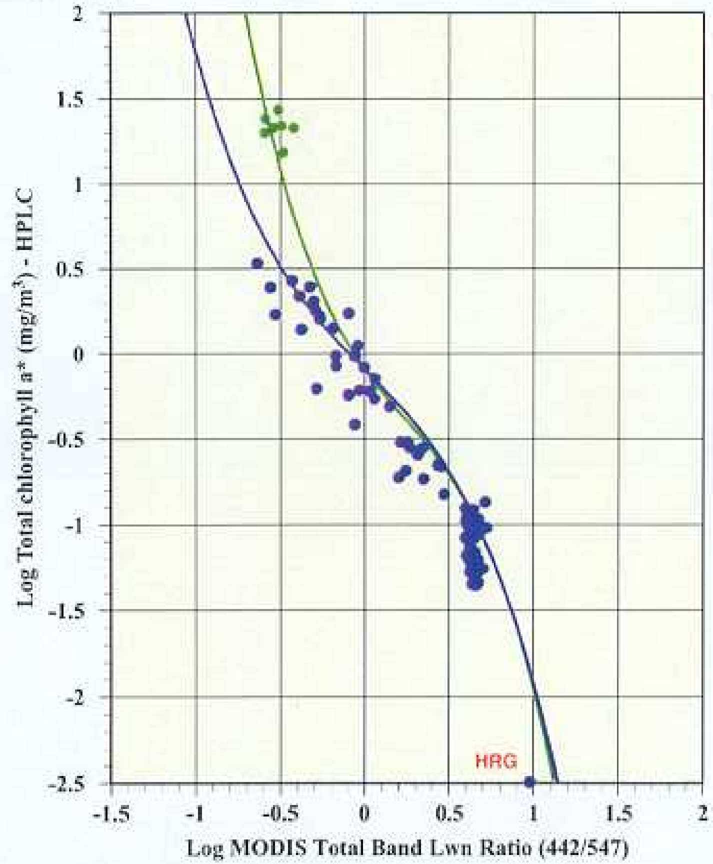


f(x) = -1.742E+0*x^3 + 1.625E+0*x^2 + -1.495E+0*x + -7.938E-2
R0^2 = 9.116E-1

f(x) = -1.338E+0*x^3 + 1.213E+0*x^2 + -1.497E+0*x + -2.273E-2
R0^2 = 9.207E-1

Figure 8. Product Number - MOD 19 Parameter 14, chlor_MODIS Day 345, 2000

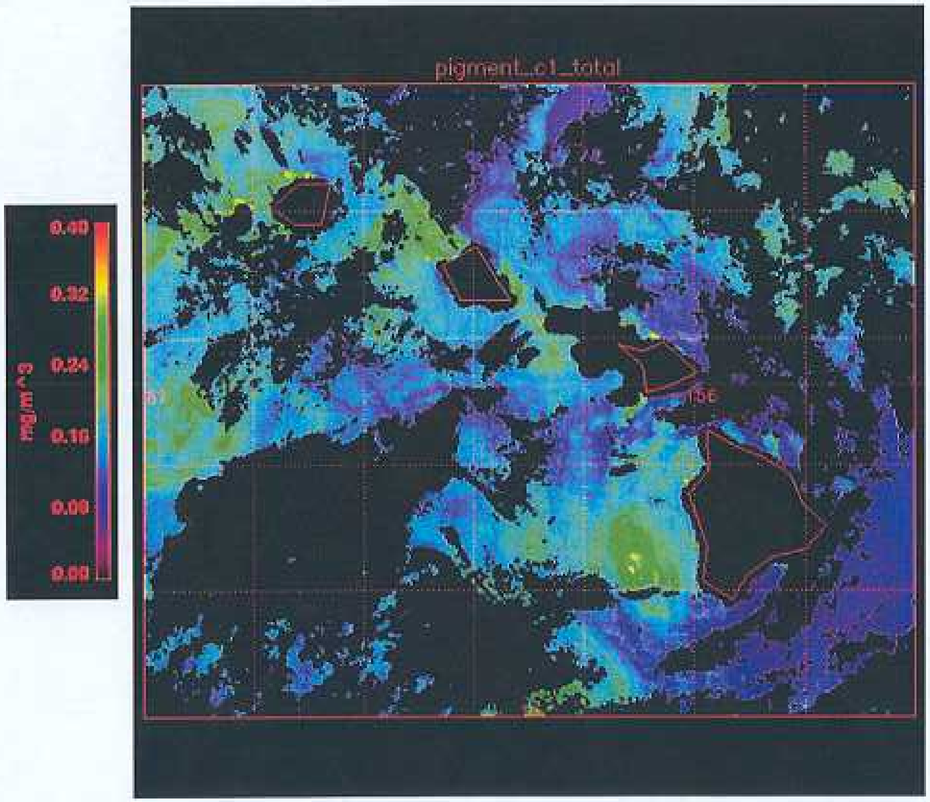


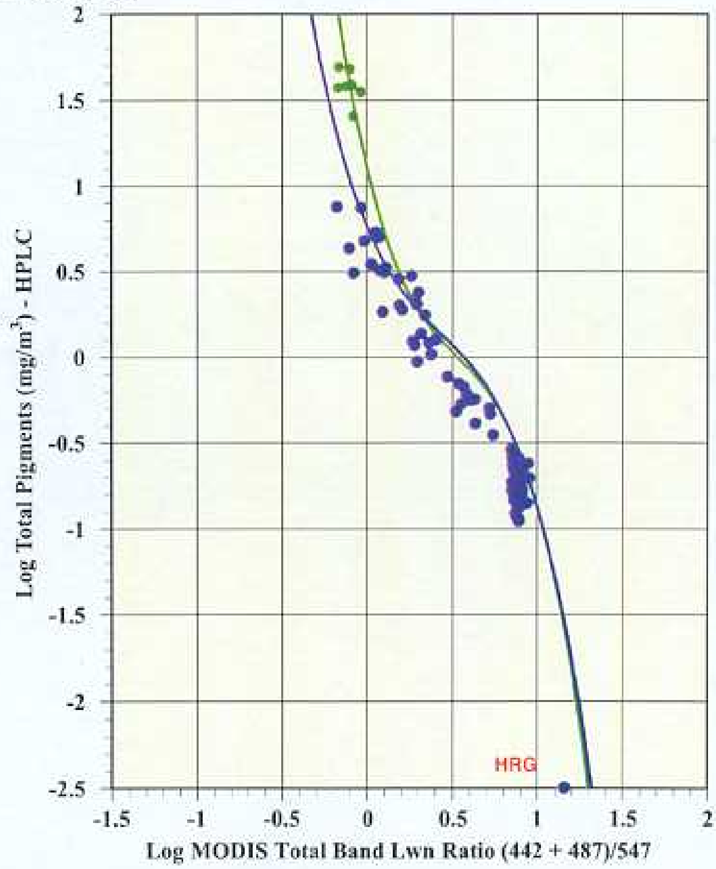


f(x) = -1.594E+0*x^3 + 1.122E+0*x^2 + -1.396E+0*x + -9.221E-2
R0^2 = 9.153E-1

f(x) = -8.622E-1*x^3 + 1.953E-2*x^2 + -9.883E-1*x + -9.318E-2
R0^2 = 9.361E-1

Figure 9. Product Number - MOD 19
Parameter 15, pigment_cl_total
Day 345, 2000

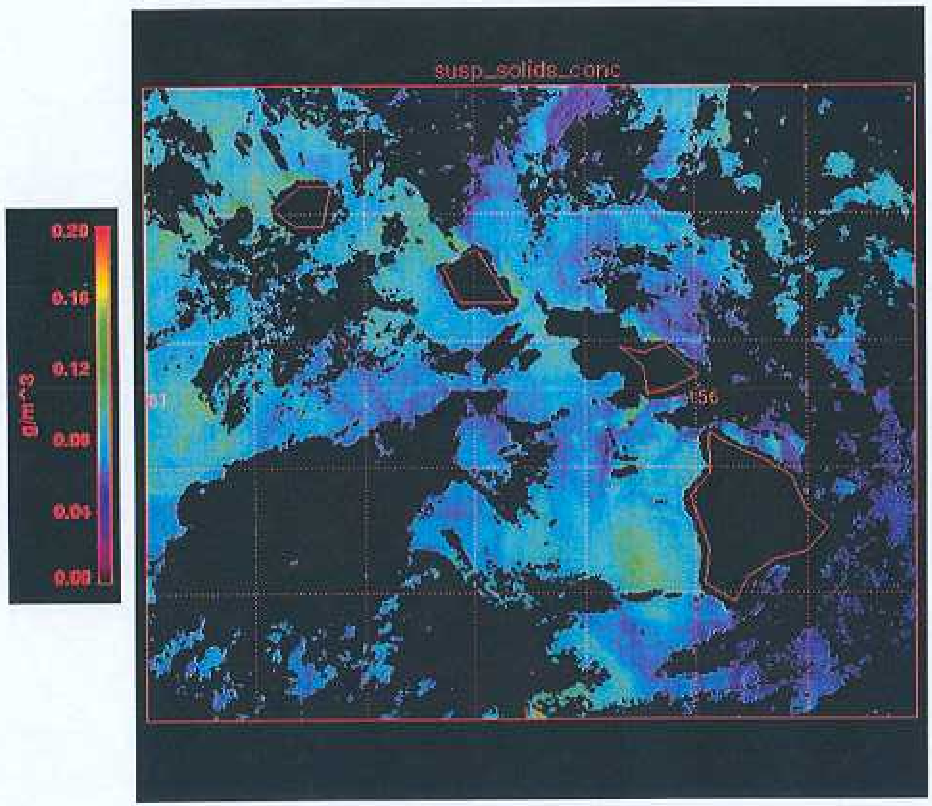


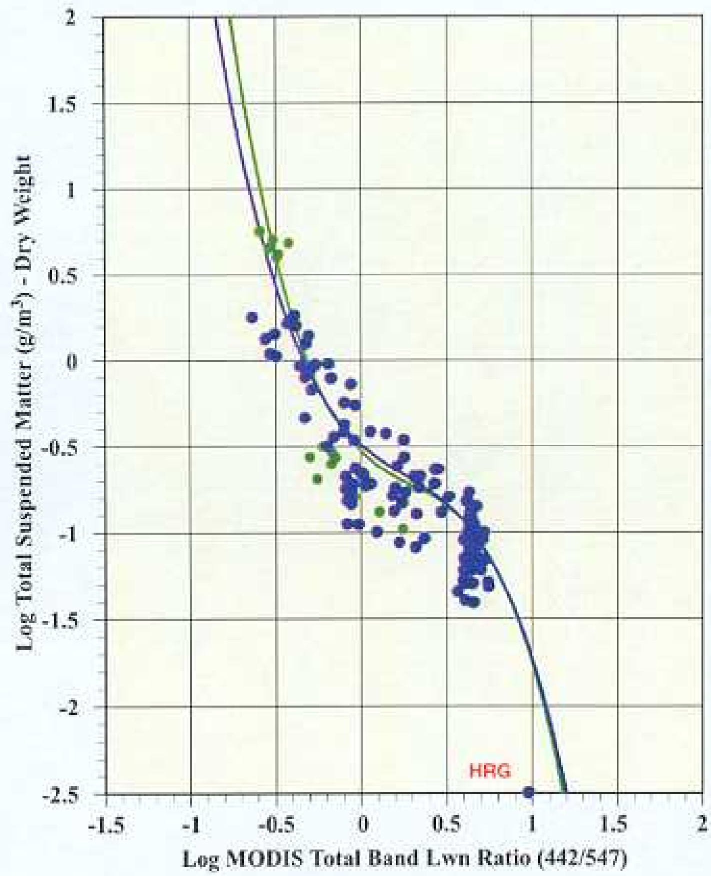


f(x) = -3.848E+0*x^3 + 6.106E+0*x^2 + -4.250E+0*x + 1.109E+0
R0^2 = 9.341E-1

f(x) = -2.550E+0*x^3 + 3.292E+0*x^2 + -2.393E+0*x + 7.644E-1
R0^2 = 9.396E-1

Figure 10. Product Number - MOD 23 Parameter 19;,Total Suspended Matter Day 345, 2000

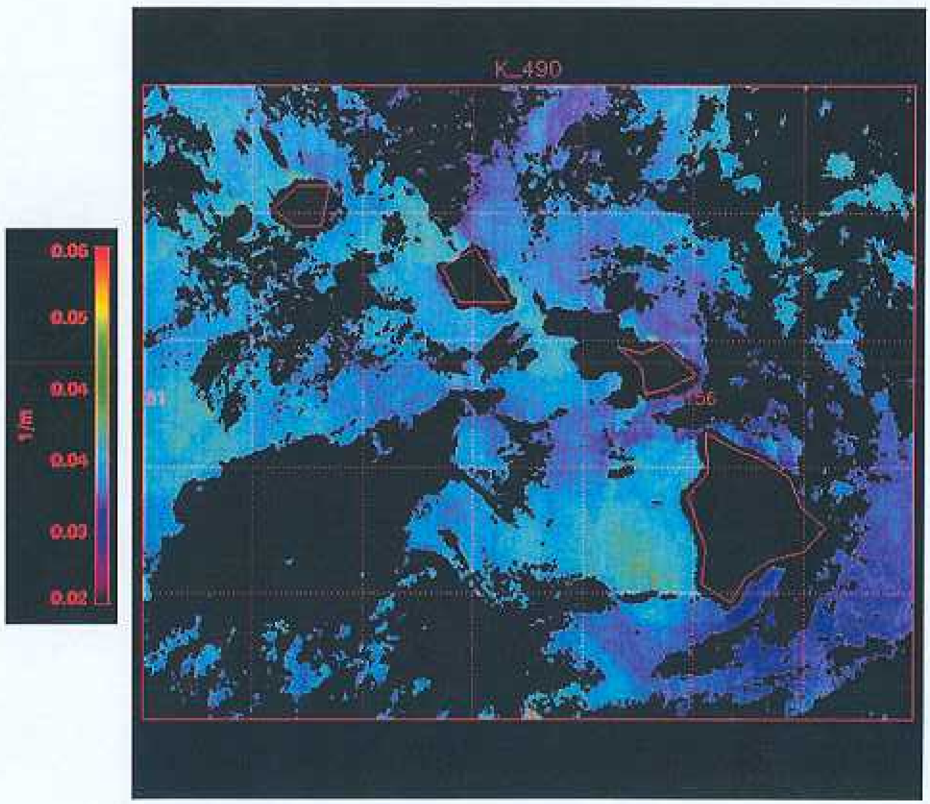


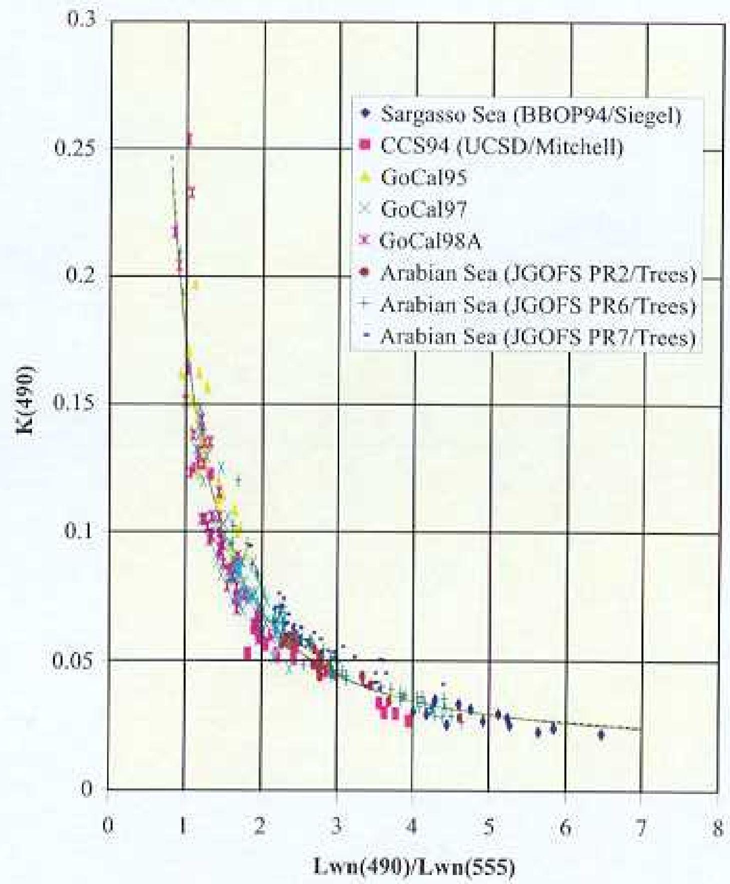


f(x) = -1.902E+0*x^3 + 1.659E+0*x^2 + -9.883E-1*x + -5.307E-1
R0^2 = 8.309E-1

f(x) = -1.513E+0*x^3 + 1.170E+0*x^2 + -9.002E-1*x + -4.901E-1
R0^2 = 7.977E-1

Figure 11. Product Number - MOD 26 Parameter 23;,K_490 Diffuse Coefficient Day 345, 2000





$$K_{Ed}(490) = 0.016 + 0.15645\left[\frac{nL_w(488)}{nL_w(547)}\right]^{-1.5401}$$

R0^2 = 9.4E-1

Appendix 1: Calibrations and maintenance schedules for MLML standards and instruments

• SLM

19-Jul-2001	Post-L69	OL425-W6D100 after MOBY216 LuB,M,T
20-Jul-2001	Post-L69	GS5000-F453 after MOBY216 EdB,M,T,S
25-Jul-2001	Post-L69	OL425-W6D100 after MOS204cfg05 Lu
03-Aug-2001	Post-L69	OL425-W6D100 after MOS204cfg06 Lu
12-Sep-2001	Pre-L72	OL425-W6D100 after MOBY218 LuB,M,T
14-Sep-2001	Pre-L72	GS5000-F454 after MOBY218 Eu,EdB,M,T,S
19-Sep-2001	Pre-L72	GS5000-F453 before&after MOS202cfg08 Ed & SIS101cfg04 Es
20-Sep-2001	Pre-L72	OL425-W6D100 after MOS202cfg08 Lu
08-Nov-2001	Post-L72	OL425-W6D40 after MOBY217 LuB,M,T
10-Nov-2001	Post-L72	GS5000-F454 after MOBY217 Eu,EdB,M,T,S

• SIS101

16-Aug-2001	NIST-2001#3	S01, SIS101cfg04 Es via X-SIRCUS R6G - 580:607 nm
19-Sep-2001	Pre-L72	SIS101cfg04 Es via GS5000-F453

• MOS202

19-Sep-2001	Pre-L72	MOS202cfg08 Ed via GS5000-F453
20-Sep-2001	Pre-L72	MOS202cfg08 Lu via OL425-S3W6D100

• MOS204

25-Jul-2001	Pre-L69	MOS204cfg05 Lu via OL425-S3W6D100
03-Aug-2001	Pos-L69	MOS204cfg06 Lu via OL425-S3W6D100 << Pre-MOBY218 >>
10-Aug-2001	NIST-2001#3	S01, MOS204cfg06 Lu via X-SIRCUS R6G - 579:600 nm
10-Aug-2001	NIST-2001#3	S02, MOS204cfg06 Lu via X-SIRCUS R6G - 585:594 nm
11-Aug-2001	NIST-2001#3	S03, MOS204cfg06 Lu via X-SIRCUS Ti:S - 768:776 nm
12-Aug-2001	NIST-2001#3	S04, MOS204cfg06 Lu via X-SIRCUS Ti:S - 837:845 nm
12-Aug-2001	NIST-2001#3	S05, MOS204cfg06 Lu via X-SIRCUS Ti:S - 735:855 nm
14-Aug-2001	NIST-2001#3	L01, MOS204cfg06 Lu via HeNe - 543.5 nm
14-Aug-2001	NIST-2001#3	L01, MOS204cfg06 Lu via HeNe - 594 nm
14-Aug-2001	NIST-2001#3	L01, MOS204cfg06 Lu via HeNe - 633 nm
14-Aug-2001	NIST-2001#3	L01, MOS204cfg06 Lu via HeNe - 612 nm
15-Aug-2001	NIST-2001#3	L02, MOS204cfg06 Lu via Ar+ - 458:514 nm
15-Aug-2001	NIST-2001#3	L02, MOS204cfg06 Lu via Diode - 412 nm

• MOS205

• MOBY216

19-Jul-2001	Pos-L69	LuB,M,T via OL425-S3W6D100
20-Jul-2001	Pos-L69	EdB,M,T,S via GS5000-F453

• MOBY217

06-Oct-2001	NIST-2001#4	LuB,M,T via Colored Source-BG28/PER/BG39/I700

07-Oct-2001	NIST-2001#4	LuB,M,T via X-SIRCUS R6G
08-Oct-2001	NIST-2001#4	LuB,M,T via X-SIRCUS R6G
09-Oct-2001	NIST-2001#4	LuB,M,T via X-SIRCUS Ti:S
10-Oct-2001	NIST-2001#4	LuB,M,T via X-SIRCUS Ti:S
11-Oct-2001	NIST-2001#4	LuM via X-SIRCUS Doubled Ti:S
13-Oct-2001	NIST-2001#4	LuB,M,T via Discrete Lasers
14-Oct-2001	NIST-2001#4	LuB,M,T via Discrete Lasers
14-Nov-2001	NIST-2001#4	Ed,EdB,M,T,S via Discrete Lasers
08-Nov-2001	Post-L72	LuB,M,T via OL425-W6D100
10-Nov-2001	Post-L72	Eu,EdB,M,T,S via GS5000-F454

• MOBY218

12-Sep-2001 Pre-L72 : LuB,M,T via OL425-S3W6D100

14-Sep-2001 Pre-L72 : EuMOS, EdB,M,T,S via GS5000-F454

APPENDIX 2

NIST 2001_04 Trip Report
MOBY Snug Harbor Support Facility
October 1 to 16, 2001

Participants: Steve Brown, Carol Johnson,
Mike Feinholz, Stephanie Flora, Mark Yarbrough, Terry Houlihan, Dennis Clark

Summary

Objectives

(1) Correct problem with VisSR for validation measurements with Colored Source.
(2) Get doubled Ti:S working for blue stray light out of band measurements.
(3) MOS Profiler finished; MOCE data sets corrected.
(4) Finish calibration of FOS; develop and implement stray light correction (SLC) algorithm; verify with Colored Source measurements. Check/correct representative set of FOS data.
(5) Finish calibration of SIS; develop and implement stray light correction algorithm; verify with Colored Source measurements. Check/correct representative set of SIS data.
(6) Measure MOBY217 in tent with lasers (several arms, out of band; in-band if necessary) and with Colored Source for validation of SLC algorithm.
(7) Measure L_u MOS205 in Cal Van (in-band and out-of-band).

Results

(1) The problem with the VisSR was identified and corrected by using a different preamplifier for the PMT.
(2) Traveling SIRCUS successfully re-installed in Calibration Hut and used in the tent with the optical fiber. Tunablility in the 408 nm to 413 nm spectral range was achieved using the intra-cavity doubling of the Ti:sapphire laser. We also used a new diode laser at 440 nm and two laser diode units, one at 645 nm and the other at 660 nm.
(3) Modeling work continued on the MOS Profiler, but we did not finish. We still need to improve the treatment of the 2^{nd} order interreflections and finish testing the MLML implementation of the SLC algorithm.
(4) The Lu port of FOS was characterized in two spectral regions, giving in-band profiles for the visible and near infrared spectrographs. The SLC parameters were estimated and applied to the FOS measurements the Colored Source. However, the correction is not working, and this is attributed to the influence of zero order.
(5) SIS was not measured during this trip.
(6) MOBY217 was thoroughly studied. For LuMID, fine scans (every 0.1 nm) were done from 585 nm to 595 nm and 815 nm to 825 nm; for LuBOT and LuTOP, the same regions were covered but the step was about 0.2 nm. Data were also taken on LuMID from 408 nm to 414 nm, but there are problems with this data set that we believe arise from a portion of the laser fundamental (816 nm to 828 nm)

affecting the results. All three arms were characterized for the location and shape of the 2nd order reflection peak using the Ti:Saph laser (735 nm to 860 nm in steps of 10 nm to 15 nm) and a number of fixed wavelength lasers (Ar-Ion, HeNe, and diode lasers). The Lu port of all three arms measured the Colored Source and this is a good data set except for the interference filter centered at 700 nm (I700); here it appears we were saturated over the center of the passband with MOBY217.

(7) We did not measure LuMOS for MOBY217, because this would have required waiting a week for the post-calibrations of the radiance and irradiance inputs to the buoy. Instead, the team will continue with the normal procedures (buoy and MOS refurbishment) and we will characterize LuMOS205 just prior to its installation in MOBY219 (February 2002).

Expanded Summary

The systems NIST brought are given in Table 1.

Table 1.

SYSTEM	COMPONENTS	COMMENTS
Traveling SIRCUS		Fine scans and reflection peaks
	Solid state pump laser	
	Tunable dye laser	580 nm to 600 nm
	Tunable Ti:Saph laser	735 nm to 855 nm
	Doubled Ti:Saph laser	408 nm to 413 nm
	30 cm integrating sphere with monitor photodiode	"NPR-Jr"
	Standard trap detector	Determine radiance
	Optical fiber	Couple to NPR-Jr from lasers
	Miscellaneous diagnostic equipment (e.g., wavemeter)	
Fixed Lasers		Coarse "scans" and reflection peaks
	Ar-Ion (air-cooled)	458 nm, 488 nm, 514.5 nm
	Four HeNe's	543.5 nm, 594 nm, 612 nm, 632.8 nm
	Diode laser	412 nm (nominal)
	Diode laser	440 nm (nominal)
	Diode laser	645 nm (nominal)
	Diode laser	660 nm (nominal)
OL420		Colored Source
	NIST OL420 with monitor photodiode	Shunt voltage, lamp voltage, and photodiode voltage are logged in file
	Filters	PER, BG28, BG39, I700
VisSR		1/8 m Fastie Ebert
	1800 l/mm, blaze at 250 nm	
	PMT (R928)	
	Two order sorting filters	320 nm and 400 nm LP

The instruments that were measured are given in Table 2.

Table 2.

SYSTEM	INPUT OPTICS	COMMENTS
MOS205	Lu TOP	MOBY217
	Lu MID	MOBY217
	Lu BOT	MOBY217
FOS VIS and NIR	Lu	

A detailed schedule of activities appears at the end of this document, organized by date and type of measurement (Tables 3 to 8).

Fine Scans

After each measurement set, the result of the fine scans was examined to see if the results were satisfactory. This involved background subtracting, normalizing for integration time and bin factor, averaging like scans, and then dividing these count rates (in ADU/pixel/s) for all columns at each laser wavelength by the net monitor voltage readings for that wavelength. Then, one column was selected and this normalized response was found for all the input laser wavelengths in the fine scan data set. The results for the dye laser and the three Lu arms are shown in Figs. 1 and 2, for the blue spectrograph (BSG) and the red spectrograph (RSG), respectively. The columns selected were 419 and 569 (the column index is from 1 to 1024, with the BSG = 1 to 512 and the RSG from 513 to 1024). There are some issues with the LuTOP and LuMID in terms of the shape and symmetry, but this may be reconciled after more analysis.

Figures 3 and 4 are the results for FOS. The dye laser was used for the VNIR Lu system in FOS, and the results in Fig. 3 are for pixel 409. The Ti:sapphire laser was used for the NIR Lu system, and the results in Fig. 4 are for pixel 365. With the dye laser, signal is present on the NIR array as well, so for the scans from 580 nm to 600 nm data were acquired with both systems.

Reflection Peaks/Coarse Scan

The Ti:sapphire laser, four diode lasers (see Table 2), an air-cooled Ar-ion laser, and four different HeNe lasers were used with LuTOP, LuMID, and LuBOT. Figure 5a shows the peak-normalized results for the BSG and the subset of discrete lasers that were used with all three Lu arms. Figure 5b shows the results of the Ti:Saph laser and Lu BOT. For the BSG, the reflection peak does not show up at 412 nm, but is there at 440 nm, and has disappeared by 580 nm. For the RSG, the reflection peak is just at the blue edge with the 645 nm input, and it is gone by about 810 nm (a slight effect is evident).

Algorithm

Besides the less than successful work with FOS (because of the zero order effects), where the parameters were developed and applied to the colored source measurements, we used the MOS Profiler parameters and applied them to MOBY217 in-water measurements. The results were encouraging, see Fig. 6. The source radiance is very blue for MOBY and previous data sets from MOCE with blue water had indicated that this was going to be very difficult to correct. However, even with the wrong SLC parameters, the red/blue offset is much reduced, especially for the arms. Since Lu MOS is still off, could this be from the larger influence of the reflection peaks?

Colored Source

The VisSR was calibrated with the OL425 twice, once as part of the FOS validation study, and once for MOBY217. Figure 7 is the result of the spectral radiance of the NIST OL420 sphere source (the Colored Source) when filtered with a BG28 filter or a PER (photopic) filter as determined with the VisSR. The Lu input for FOS and the three MOBY217 arms measured the Colored Source and the results will be used to evaluate the SLC algorithm.

Action Items:

The poor repeatability of the trap/monitor calibrations (seen in August): what is the cause, and are we seeing it here? It does not happen every time, perhaps this is an alignment issue.

See if we can correct the Lu MID blue in-band data set from the doubled Ti:Saph using the MOBY217 results, with the pre-deployment calibration, if we assume we know the spectral response of the monitor. That is, use MOBY217 to measure the fraction of the flux that is doubled compared to the fundamental, and then use this to correct the monitor signal to a value more representative of the blue radiance.

Look at the previous deployments when the fixed wavelength lasers were used with buoys that were configured with MOS205. Are the reflection peaks the same?

Refine the work plan for the AGU talk and the SeaWiFS matchups (a draft is below).

DRAFT Work Plan for MOBY217(MOS205)

Question, can the SLC be based on the monitor-normalized results only? It is understood that all analysis involves subtracting backgrounds, adjusting for integration time and bin factor, averaging of like scans, and removal of questionable or flagged data sets. Here XS means traveling SIRCUS.

In-Band

1a. Derive Lxs for inband scans, ignore 2xTi:saph data for now.

1b. Process MOBY217 XS files, results are pixel count rates per radiance (ADU mm2 sr)/(pixel sec W).

1c. Plot the column radiance response (fixed CCD column; all in-band XS wavelengths), for LuTOP, LuMID, LuBOT. For R6G there will be a BSG and a RSG column, for the Ti:saph, only a RSG column. Select a column that was in the middle of the region scanned with the XS wavelengths.

1d. Write an ascii file of these results, there will be a different set for each arm, the column selected, and the laser type; the x-data are the XS wavelengths and the y-data are the ADU/pxl/sec/Lxs responses. We use these data to find the in-band area.

1e. For LuMID and the column selected in 1c, identify the XS wavelength that gave the maximum column response and write an ascii file of the "spatial results", e.g. the result at all columns for that XS "max" wavelength. The x-axis is column and the y-axis ADU/pxl/sec/Lxs. We use this to set the level of the maximum response to the out of band, and we use the shape to fit the out of band to some analytical function.

1f. Use 1d and 1e results to get the parameters in the SLC algorithm. This is all that is needed for an instrument that does not have the 2nd order reflection peaks.

Reflection Peaks

2a. For all fixed wavelengths measured, including the widely-spaced Ti:saph wavelengths, and possible one or two typical wavelengths from the in-band scans: convert to ADU/pxl/sec.

2b. Evaluate running averages (over 10 or so columns) to get a more accurate estimate of the maximum value, and hence the actual ratio of the peak to the out of band, and then normalize by the maximum value.

2b. Plot all measurements for each Lu arm together, for presentation purposes, with the x-axis in column number (pixel) as well as with the MOBY217 wavelength calibration.

2c. (this is an aside) Determine the exact wavelengths for the diode lasers, either by using the MOBY217 wavelength calibration or by ancillary measurements at NIST.

2d. Make an ascii file of these spatial scan results, with separate files for each arm, the first column corresponding to the CCD column and subsequent columns labeled by the nominal fixed wavelength of the input flux.

2e. If possible, include previous measurements with this buoy: We had MOS205 (MOBY215) for the March 2001 deployment, in which case we used the Ar-Ion and two HeNes with LuMID, and we also tried Lu MOS in the tent. Plot a comparison.

2f. Using the data in 2d, develop the reflection peak correction model parameters (details omitted here).

Validation with Colored Source

3a. Reduce the VisSR data to get the Colored Source spectral radiances (done, but could fiddle some more with comparing different responsivity determinations from the two days etc.).

3b. For the MOBY217 measurements of the Colored Source, reduce data with the OL420 and the filters using the (upcoming) post-deployment calibration of the Lu arms (the pre-deployment responsivities would be an option). We did not take calibration source data with the OL425 and MOBY217 during our deployment, so for best results of the validation experiment, this should be done as soon as possible.

3c. Apply the SLC using the MOBY217 model parameters and compare corrected and uncorrected MOBY217 responsivities and Colored Source data.

Testing

4a. NIST and MLML should independently process as much of the data as is feasible, for some sample data sets. This ensures both implementations of the algorithms give the same results, and it will also be useful to independently derive the SLC parameters.

4b. SLC the MOBY217 in-water data, as well as all previous buoys with MOS205. Develop some measure of "goodness of procedure", e.g. the blue/red offset over some range of wavelengths. Summarize results for presentation purposes, and evaluate the adequacy of the correction.

4c. Evaluate the uncertainty in the procedure.

Implications

5a. KL's (radiance attenuation coefficients) and Lw's (water-leaving radiance)

5b. SeaWiFS—final results for gain coefficients (complicated procedure, SeaWiFS Project does using a least squares analysis of selected match-ups; they start by deriving nLw's from the MOBY Lw's)

5c. Band ratios—derive corrected ratios and assess impact on bio-optical algorithms.

Table 3. FOS in the HUT. In the FOS data files, Z = V for visible, N for near infrared, xxx = the index number (corresponds to XS wavelength) and sss is the scan number (001, 002 or 003 if three scans were done).

Inst.	Date	St Time	Radiance Files	Response Files	Instr Files	Range	Output as of October 23
	GMT (HST)	GMT				nm	
FOS Lu	Oct04 (Oct03)	01:20 01:47 04:24	XS011003_1 XS011003_3	XS011003_2	1Zxxx-1_sss	577 to 605 580 to 600 577 to 606	Mon. norm'd results (VPxl 409)
FOS Lu	Oct04 (Oct03)	05:37 06:01 07:41 08:14	XS011003_11 XS011003_15	XS011003_12 , _13 XS011003_14	2Nxxx-1_sss	792 to 815 791 to 825 800 to 814 780 to 830	First set with Vis as well (799.19) Mon. norm'd results (NPxl 364)

Table 4. FOS Validation with the Colored Source in the TENT.

Inst.	Date	St Time	Source	VisSR Files	Instr Files	Range	Output as of October 23
	GMT (HST)	GMT				nm	
VisSR	Oct05 (Oct04)	05:21 05:38	OL425	R200110050521 R200110050538	none	380 to 600 580 to 800	VisSR Inst response for Thursday
FOS Lu	Oct05 (Oct04)	06:03	OL425	none	3Zxxx-1_sss	full range	Steph analyzed for FOS system response
Both	Oct05 (Oct04)	06:21 06:33 06:50 07:09	OL420/BG28	 L200110050633 L200110050650	4Zxxx-1_sss 4Zxxx-1_sss	full 380 to 600 580 to 800 full	Spectral radiance using VisSR (Thursday calibration)
Both	Oct05 (Oct04)	07:30 07:48 08:04 08:21	OL420/PER	 L200110050748 L200110050804	5Zxxx-1_sss 5Zxxx-1_sss	full 380 to 600 580 to 800 full	Spectral radiance using VisSR (Thursday calibration)

Table 5. MOBY217(MOS205) Validation with the Colored Source in the TENT.

Inst.	Date	St Time	Source	Instr Files	Comments	Output as of October 23
	GMT (HST)	GMT				
LuBOT	Oct06 (Oct05)	00:51	OL420/BG28 OL420/PER OL420/BG39 OL420/I700	OB17LBxx	Saturated	
LuMID	Oct06 (Oct05)	02:18	OL420/I700 OL420/BG39 OL420/PER OL420/BG28	OB17LMxx	Saturated	
LuTOP	Oct06 (Oct05)	03:38	OL420/BG28 OL420/PER OL420/BG39 OL420/I700	OB17LTxx	Saturated	

We need a copy of Mike's log sheets for this data set; at the moment I'm guessing at the file names based on what is in the data archive.

Table 6. Continued calibration of the colored source with the VisSR in the TENT.

Inst.	Date	St Time	Source	VisSR Files	Range	Output as of October 23
	GMT (HST)	GMT			nm	
VisSR	Oct06 (Oct06)	21:00 21:20	OL420/BG39	L200110062100 L200110062120	380 to 600 580 to 800	Spectral radiance using VisSR (Saturday calibration)
VisSR	Oct06 (Oct06)	21:46 22:04	OL420/I700	L200110062146 L200110062204	380 to 600 580 to 800	Spectral radiance using VisSR (Saturday calibration)
VisSR	Oct07 (Oct06)	01:03 01:15	OL425	R200110070103 R200110070115	380 to 600 580 to 800	VisSR Inst response for Thursday

Table 7. MOBY217(MOS205) in the TENT with XS Sircus. In the MOBY data files, xx is the wavelength index. For the SIRCUS files, the wavelength data are in one file and the monitor or monitor and trap data are in a separate file.

Inst.	Date	St Time	Radiance Files	Response Files	Instr Files	Range	Output as of October 23
	GMT (HST)	GMT				nm	
M217 LuMID	Oct07 (Oct06)	03:55 04:33 06:31	XS011007_1m, _1 XS011007_3m, _3	XS011007_2m, _2	OB1701xx	590 to 605 585 to 595 578 to 605	Pxl 418-420 B; 568-570 R radiances derived
M217 LuTOP	Oct08 (Oct08)	20:18 20:54 23:29	XS011008_1m(w) XS011008_4m(w)	XS011008_3m(w)	OB1702xx	575 to 605 585 to 595 580 to 600	_2m ignore; _2w N/A 419/569 are compared
M217 LuBOT	Oct09 (Oct08)	02:24 03:00 05:03	XS011008_10m(w) XS011008_12m(w)	XS011008_11m(w)[1]	OB1703xx	580 to 600 585 to 595 580 to 600	419/569 are compared
M217 LuBOT	Oct09 (Oct09)	20:35 21:06 22:21	XS011009_10m(w) XS011009_12m(w)	XS011009_11m(w)	OB1704xx	812 to 827 815 to 825 812 to 828	
M217 LuBOT	Oct09 (Oct09)	22:48	Not needed for reflection peaks	XS011009_13m(w)[2]	OB1705xx	735 to 860	plot of RPs somewhere?
M217 LuMID	Oct10 (Oct09)	01:05 01:32 04:03	XS011009_20m(w) XS011009_22m(w)	XS011009_21m(w)	OB1706xx	811 to 827 815 to 825 813 to 827	includes RPs 734 to 836
M217 LuTOP	Oct10 (Oct10)	19:40 20:06 21:38	XS011010_10m(w) XS011010_12m(w)	XS0110010_11m(w)	OB1707xx	816 to 824 815 to 825 812 to 826	includes RPs 733 to 860
M217 LuMID	Oct11-12 (Oct11)	20:56 01:35 21:38	No trap/monitor calibration was done	XS0110011_10, XS0110011_11, XS0110011_12[3]	OB1708xx	408 to 414	Pxl xxx analyzed

1. Index number 1 (the first record) went into the *_10 files by mistake.
2. Don't need the monitor files, either.
3. Wavemeter not read; no automatic wavelength data, see log sheets. (Independent sets by Steve, Mike, Carol)

Table 8. MOBY217(MOS205) in the TENT with discrete, fixed-wavelength lasers (although the 645 nm and the 660 nm diode lasers are tunable using temperature or current control, they were operated at 25 °C and 60 mA, for only one wavelength). In the MOBY data files, xx designates the measurement—multiple MOS configurations were used (integration times and bin factors).

Inst.	Date	Start Time	Instr Files	Laser Type	Wavelength	Refl. Peaks?
	GMT (HST)	GMT			nm	
M217 LuMID	Oct13 (Oct12)	01:39	OB1709xx	Ar-Ion	514.5	Y(blue)
		02:00			476[1]	Y(blue)
		02:09			458	Y(blue)
		02:20		HeNe	632.8	N(blue, red)
		02:30			543.5	Y(blue)
		02:42			612	N(blue, red)
		02:54			594	N(blue, red)
		03:09		Diode	440	Y(blue)
		03:21			412	N(blue)
M217 LuMID	Oct13-14 (Oct13)	22:13	OB1710xx	Diode	660	Y(red)
		00:15			645	Y(red, at Pxl 1)
M217 LuBOT	Oct14 (Oct13)	00:56	OB1711xx	Diode	660	Same pixels as LuMID
		01:19		Ar-Ion	514.5	
		01:30			488	
		01:47			476	
		01:57			458	
		02:07		HeNe	543.5	
		02:17		Diode	440	
M217 LuBOT	Oct14 (Oct13)	02:52	OB1712xx	Ar-Ion	514.5	Same pixels as LuMID
		03:02			488	
		03:10			476	
		03:17			458	
		03:27		HeNe	543.5	
		03:39		Diode	440	
		03:48		Diode	660	

1. Labeled wrong on Mike's log sheet?

Figure Captions

Figure 1. Preliminary results for the column response for one column in the BSG using the dye laser; a comparison of LuTOP, LuMID, and LuBOT is made.

Figure 2. Preliminary results for the column response for one column in the RSG using the dye laser; a comparison of LuTOP, LuMID, and LuBOT is made.

Figure 3. Preliminary results for the column response for one column in the FOS VIS Lu using the dye laser.

Figure 4. Preliminary results for the column response for one column in the FOS NIR Lu using the dye laser.

Figure 5. Reflections peaks in LuMID.

Figure 6. The results of applying the MOS Profiler SLC parameters to a MOBY217 data set.

Figure 7. The spectral radiance of the Colored Source for two of the four configurations measured.

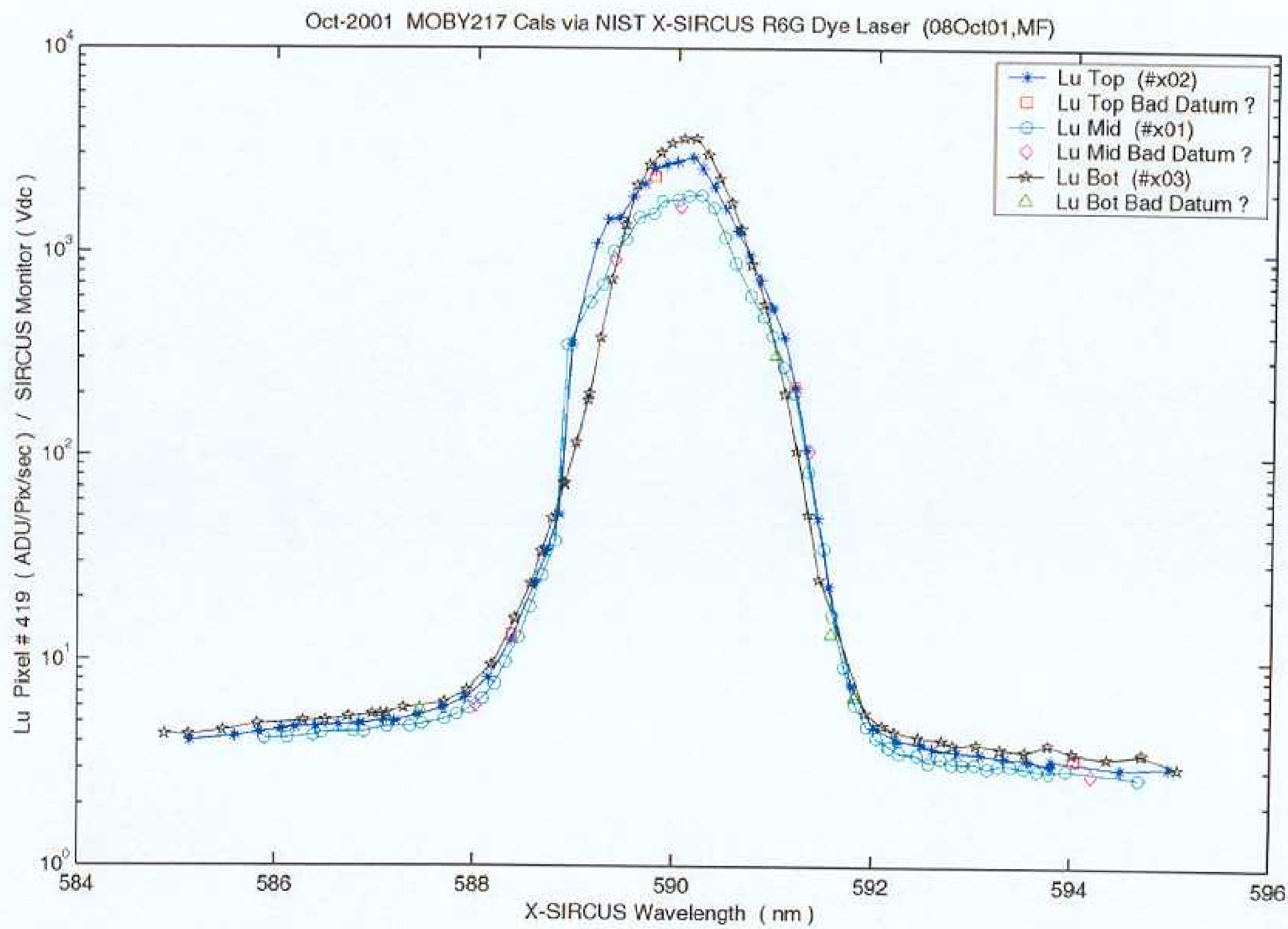

Oct-2001 MOBY217 Cals via NIST X-SIRCUS R6G Dye Laser (08Oct01,MF)
Lu Top (#x02)
Lu Top Bad Datum ?
Lu Mid (#x01)
Lu Mid Bad Datum ?
Lu Bot (#x03)
Lu Bot Bad Datum ?
Lu Pixel # 419 (ADU/Pix/sec) / SIRCUS Monitor (Vdc)
X-SIRCUS Wavelength (nm)
584
586
588
590
592
594
596
10^0
10^1
10^2
10^3
10^4

Figure 1

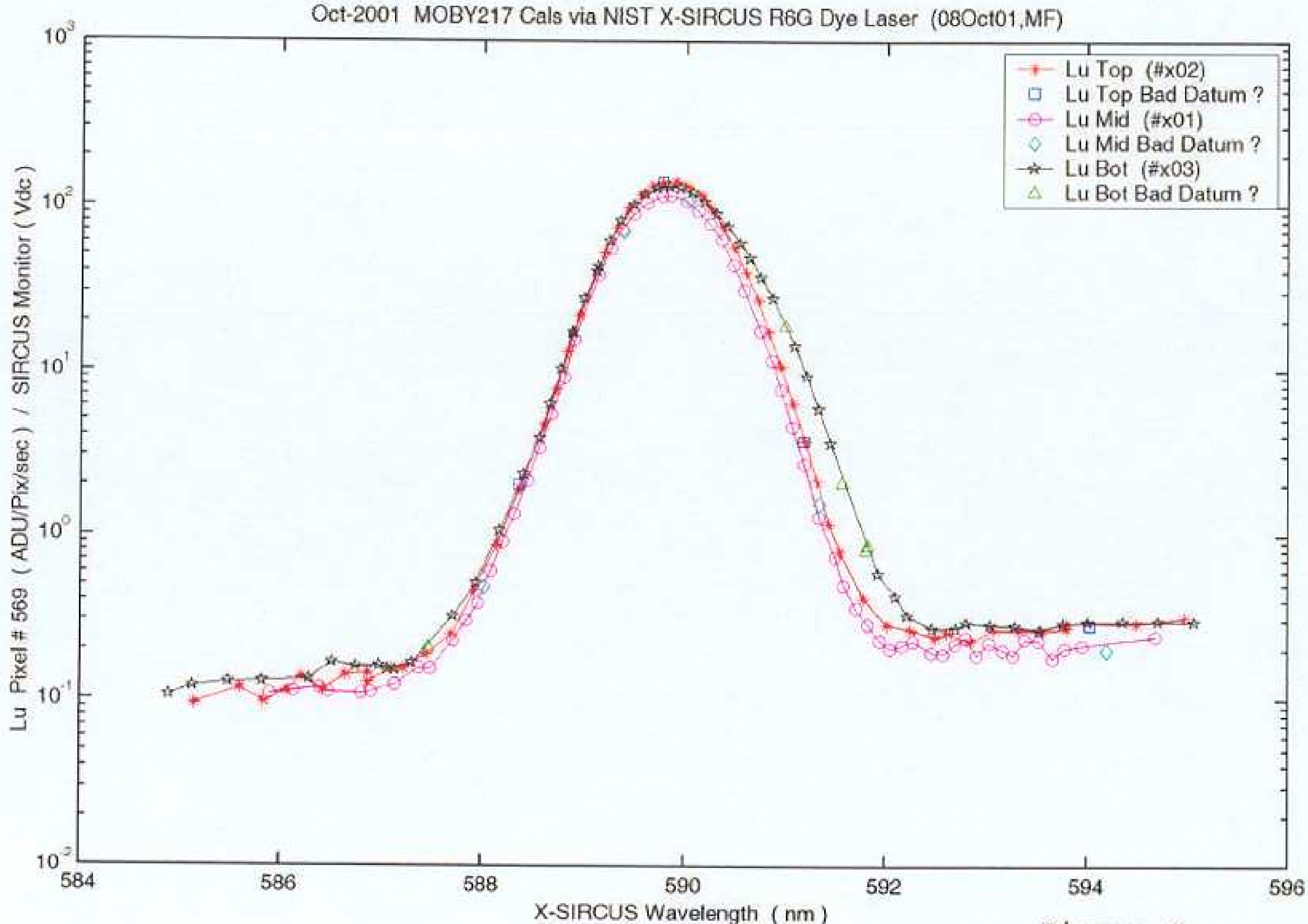
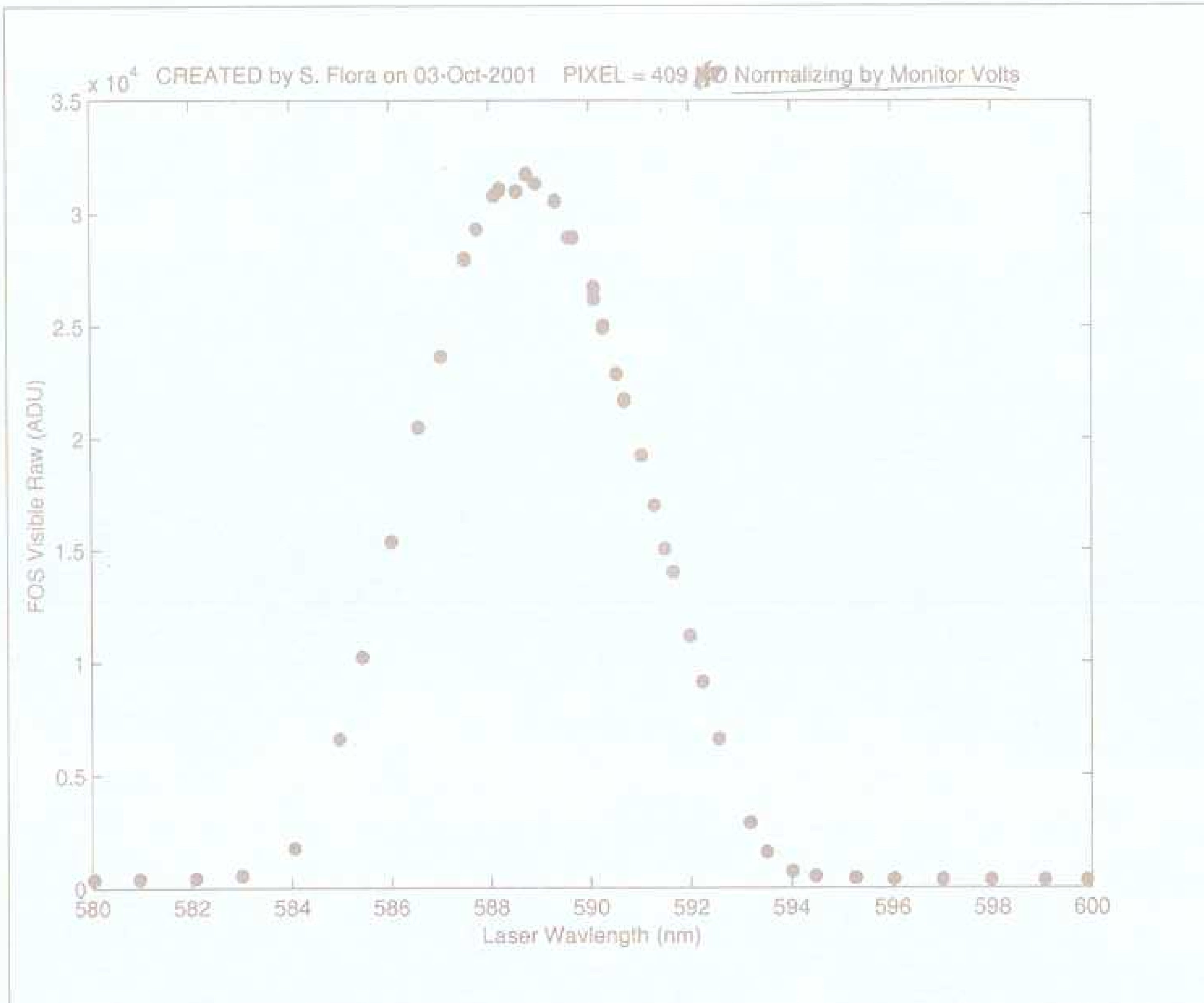

Oct-2001 MOBY217 Cals via NIST X-SIRCUS R6G Dye Laser (08Oct01,MF)
Lu Pixel # 569 (ADU/Pix/sec) / SIRCUS Monitor (Vdc)
10^-2
10^-1
10^0
10^1
10^2
10^3
584
586
588
590
592
594
596
X-SIRCUS Wavelength (nm)
Lu Top (#x02)
Lu Top Bad Datum ?
Lu Mid (#x01)
Lu Mid Bad Datum ?
Lu Bot (#x03)
Lu Bot Bad Datum ?

Figure 2


x 10^4 CREATED by S. Flora on 03-Oct-2001 PIXEL = 409
Normalizing by Monitor Volts
FOS Visible Raw (ADU)
Laser Wavlength (nm)
0
0.5
1
1.5
2
2.5
3
3.5
580
582
584
586
588
590
592
594
596
598
600

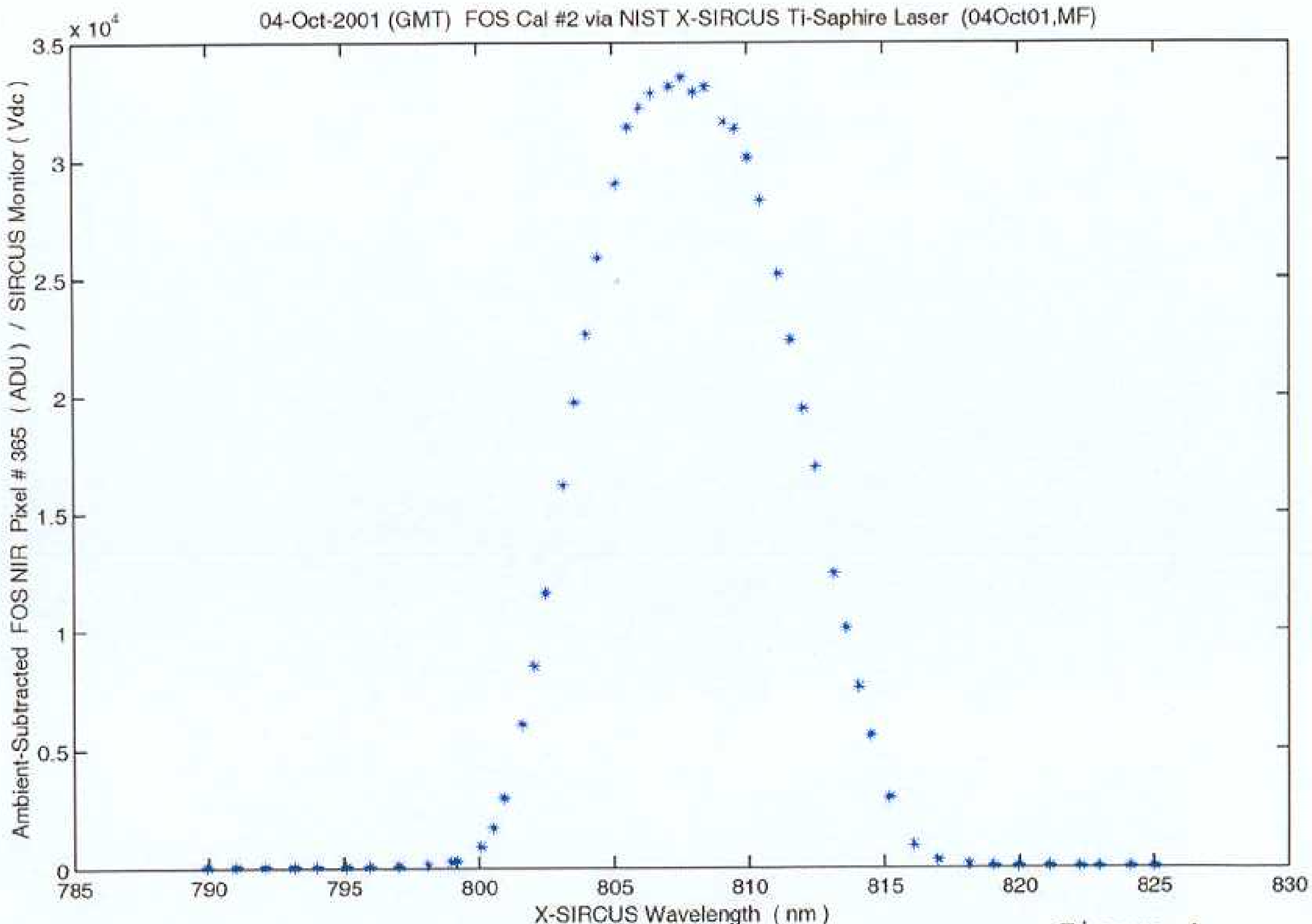

04-Oct-2001 (GMT) FOS Cal #2 via NIST X-SIRCUS Ti-Saphire Laser (04Oct01,MF)
x 10^4
3.5
3
2.5
2
1.5
1
0.5
0
Ambient-Subtracted FOS NIR Pixel # 365 (ADU) / SIRCUS Monitor (Vdc)
785
790
795
800
805
810
815
820
825
830
X-SIRCUS Wavelength (nm)

Figure 4

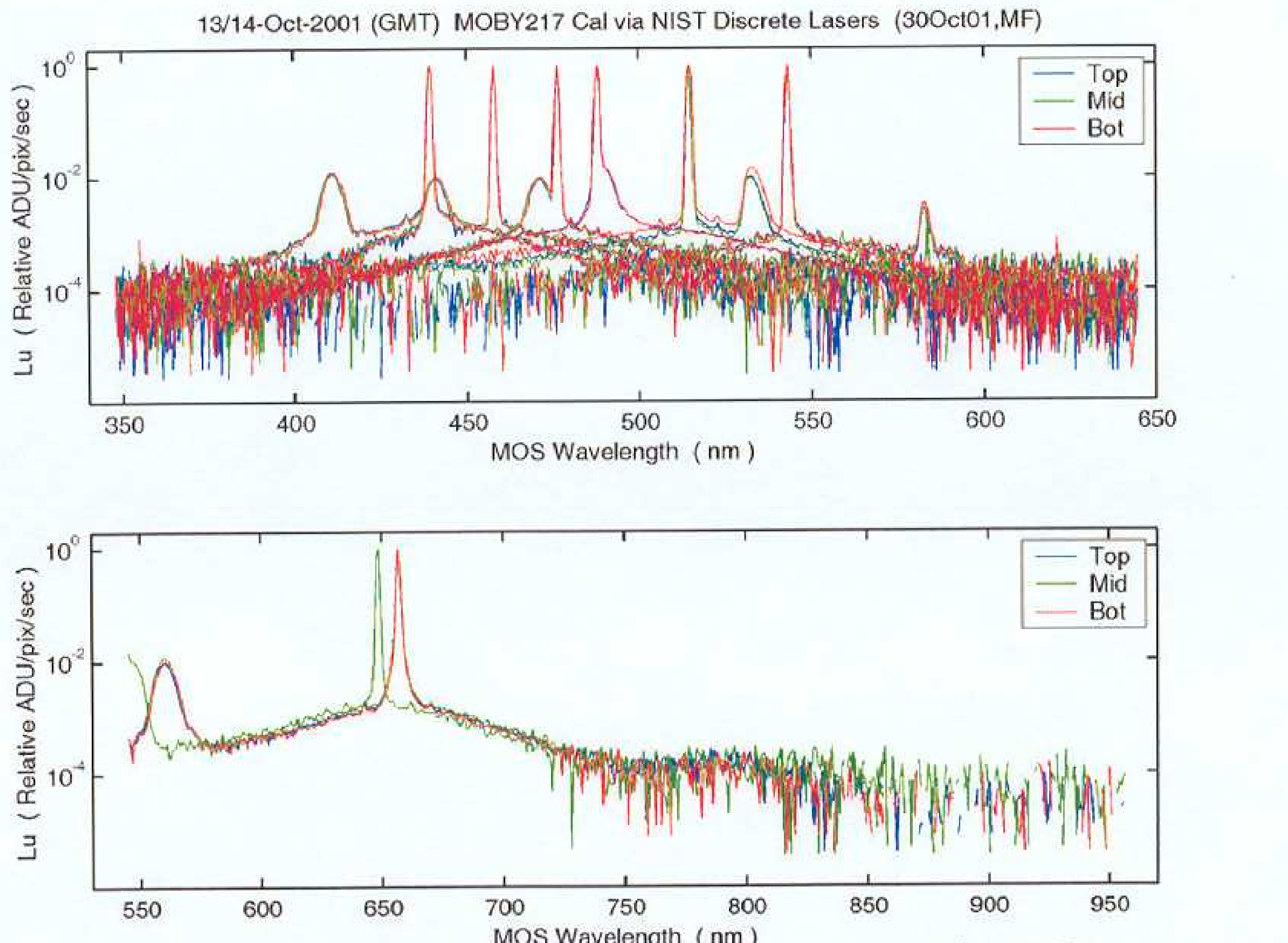

13/14-Oct-2001 (GMT) MOBY217 Cal via NIST Discrete Lasers (30Oct01,MF)
Top
Mid
Bot
Lu (Relative ADU/pix/sec)
MOS Wavelength (nm)
Top
Mid
Bot
Lu (Relative ADU/pix/sec)
MOS Wavelength (nm)

Figure 5a

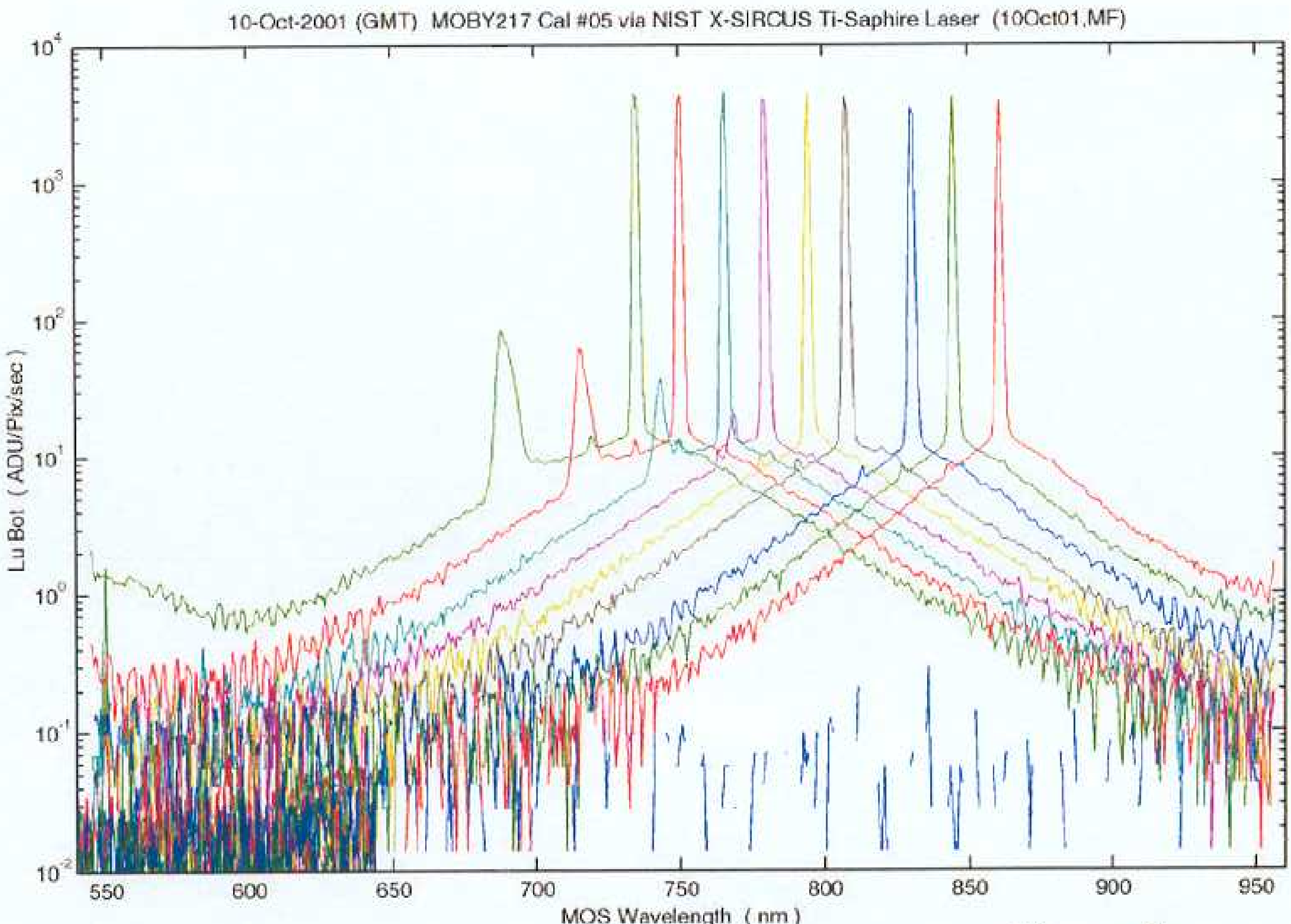
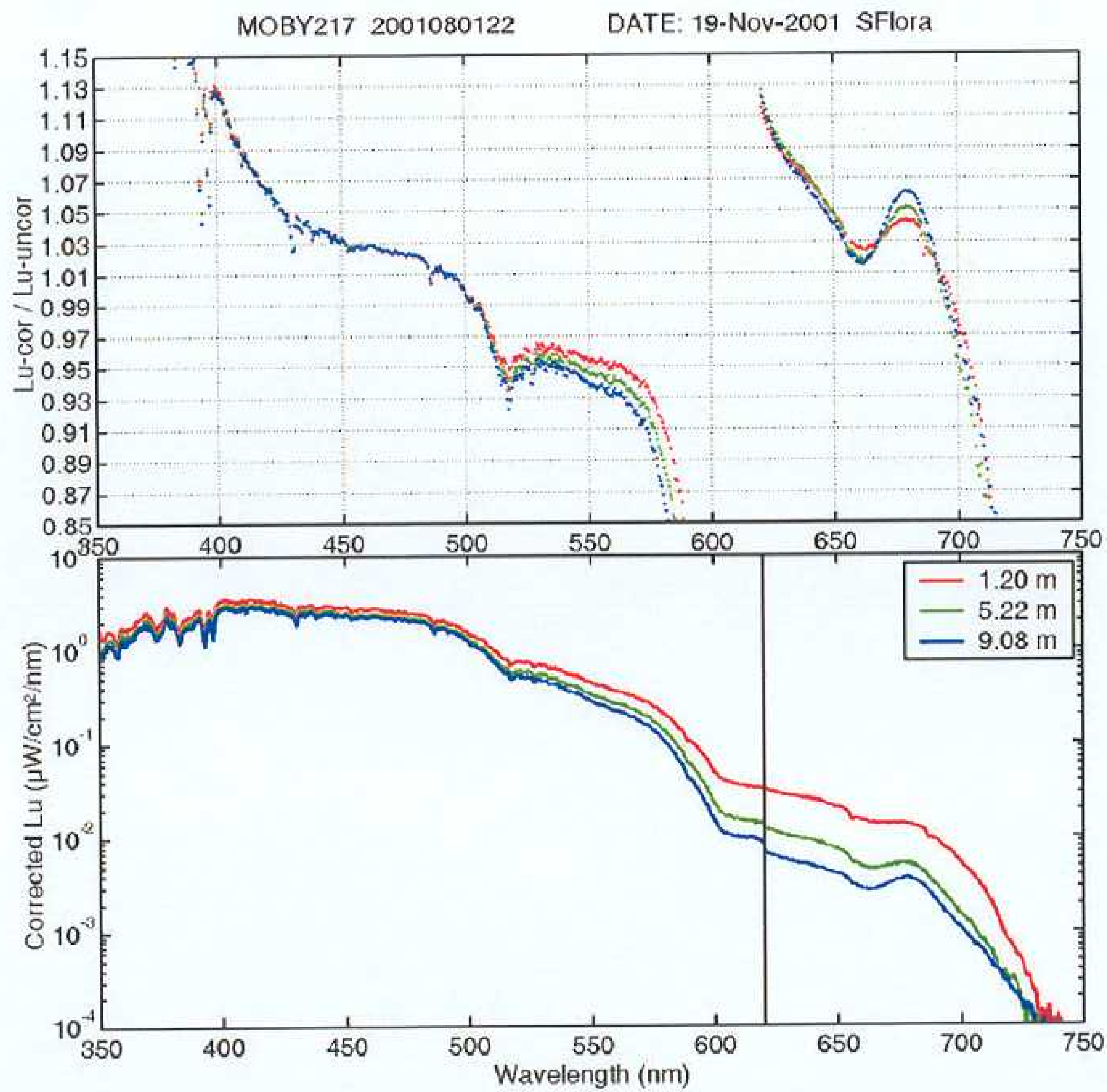
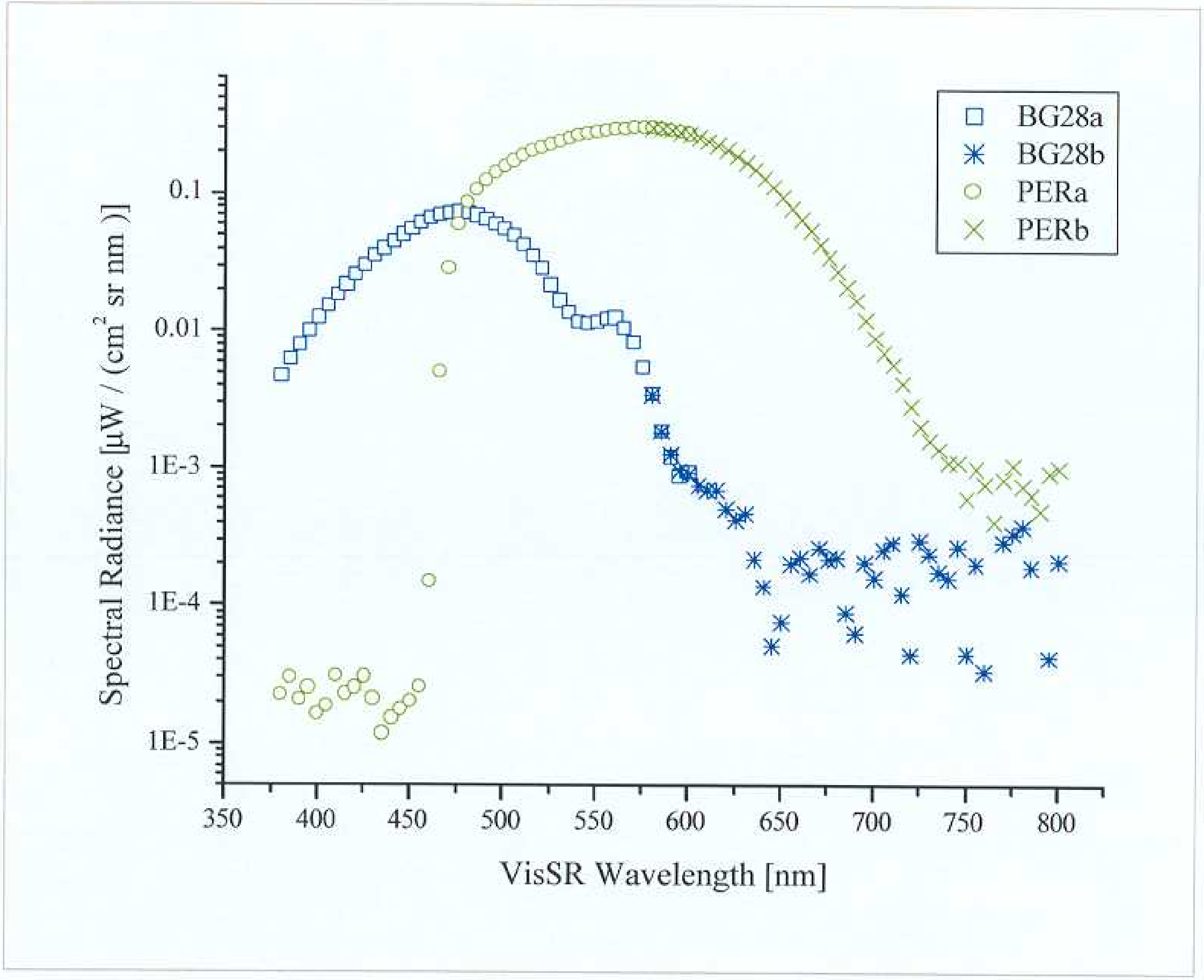

10-Oct-2001 (GMT) MOBY217 Cal #05 via NIST X-SIRCUS Ti-Saphire Laser (10Oct01,MF)
Lu Bot (ADU/Pix/sec)
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
550
600
650
700
750
800
850
900
950
MOS Wavelength (nm)

Figure 5b


MOBY217 2001080122
DATE: 19-Nov-2001 SFlora
Lu-cor / Lu-uncor
1.15
1.13
1.11
1.09
1.07
1.05
1.03
1.01
0.99
0.97
0.95
0.93
0.91
0.89
0.87
0.85
350
400
450
500
550
600
650
700
750
1.20 m
5.22 m
9.08 m
Corrected Lu (µW/cm²/nm)
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
Wavelength (nm)


BG28a
BG28b
PERa
PERb
Spectral Radiance [µW / (cm^2 sr nm)]
0.1
0.01
1E-3
1E-4
1E-5
350
400
450
500
550
600
650
700
750
800
VisSR Wavelength [nm]

APPENDIX 3

Stray Light Characterization for MOBY

Carol Johnson
NIST Optical Technology Division

Team:

D. Clark (NOAA)

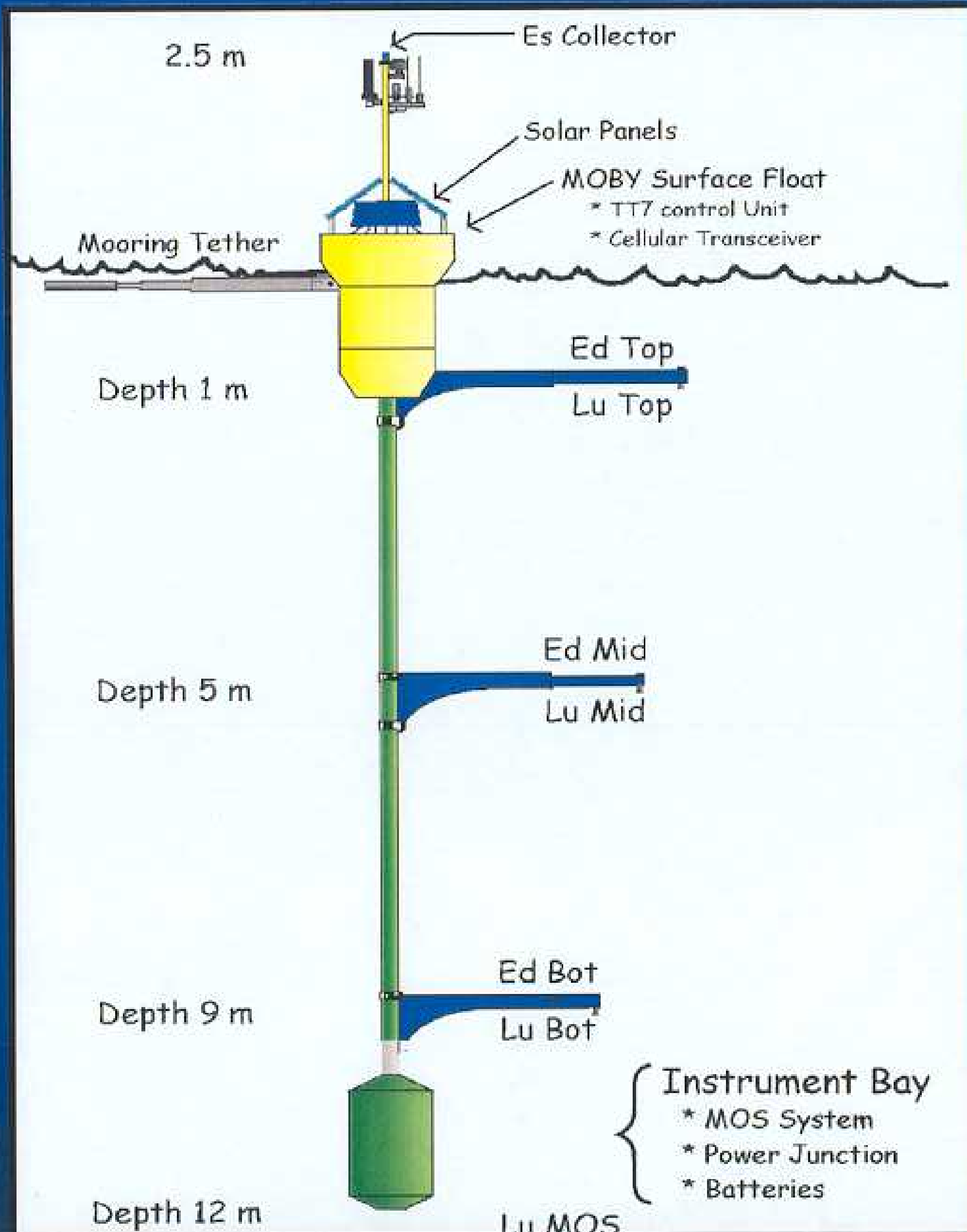
M. Feinholz, S. Flora,
M. Yarbrough (MLML)

S. Brown, C. Johnson, K. Lykke (NIST)

MOBY & MOS

MOS--
Dichroic beamsplitter and two single grating CCD spectrographs;
High resolution (<1 nm);
Wide coverage (345 to 955 nm);
Robust calibration procedures;
Profiler and buoy operation.

MOBY--
Fiber optic coupling to MOS;
Time series since 1996;
SeaWiFS and MODIS overpasses;
Band-averaged Lw's reported;
Satellite gain coefficients.



MOBY Calibration Procedures

Science requirements: 5 % nLw

MOBY is currently 4 % to 8 %; achieved using rigorous, multi-step approach

Features:

Pre- and Post Calibrations

E and L sources NIST-traceable

Sources recalibrated every 50 h

Sources verified during use with SLMs (NIST-designed radiometers)

Daily scans of three internal sources (blue and red LED; lamp)

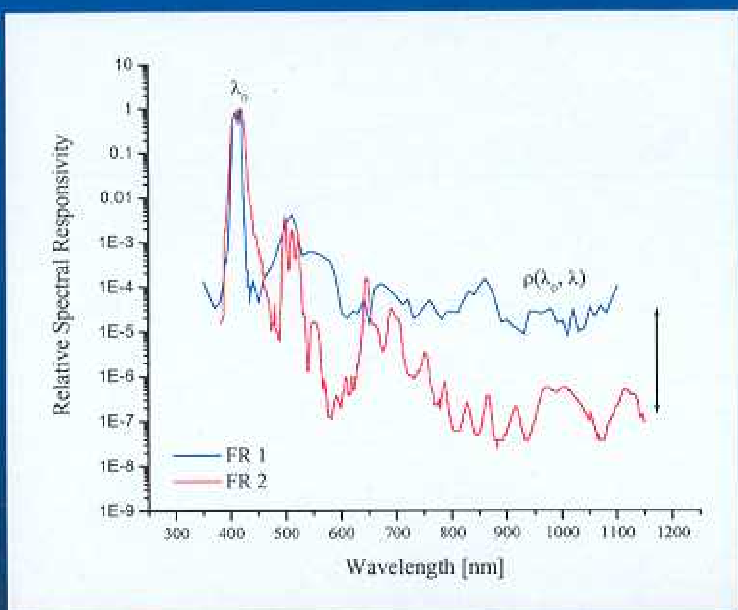
Monthly measurements with stable, diver-deployed lamps

"Stray Light" in Filter Radiometers

Relative spectral responsivity, $\rho(\lambda_0,\lambda)$

Separate function for each channel (band)

Describes response to flux at $\lambda \neq \lambda_0$



Measurement Equation

$$S(\lambda_0) = R(\lambda_0) \int \rho(\lambda_0, \lambda) L(\lambda) \, d\lambda$$

Common Simplification

$$S(\lambda_0) = R(\lambda_0) L(\lambda_0) \, \delta\lambda$$

S = Measured signal

R = System response

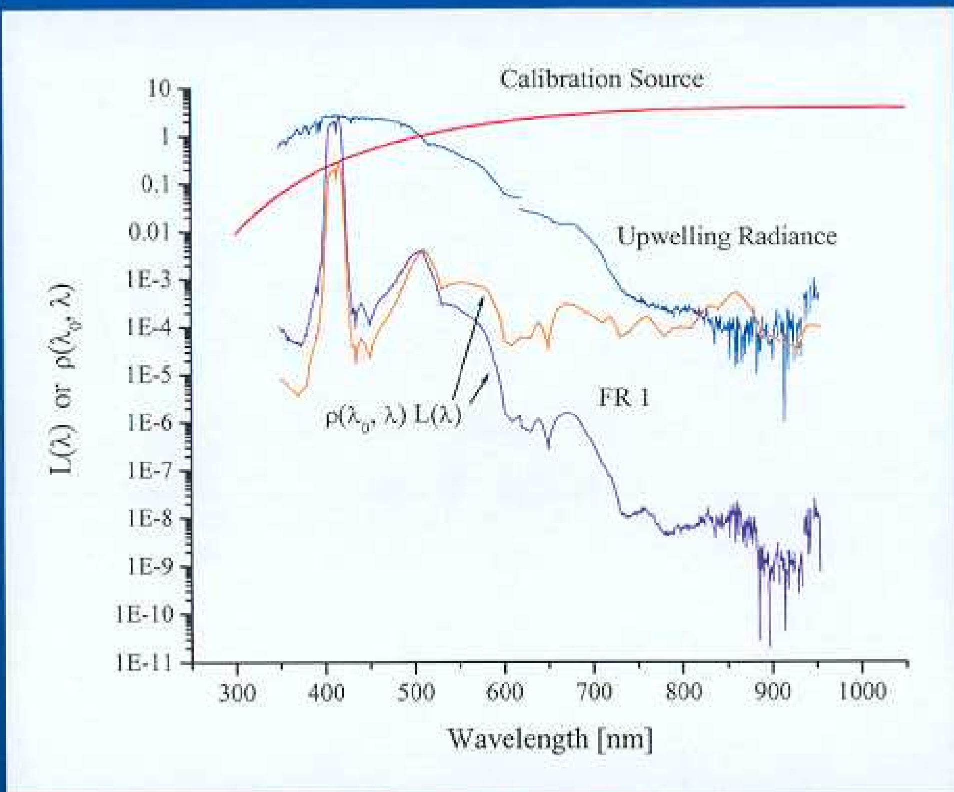
L = Spectral radiance

$\delta\lambda$ = Bandwidth of channel

λ_0 = Wavelength of channel

λ = Wavelength of flux

Result of (Over)Simplification

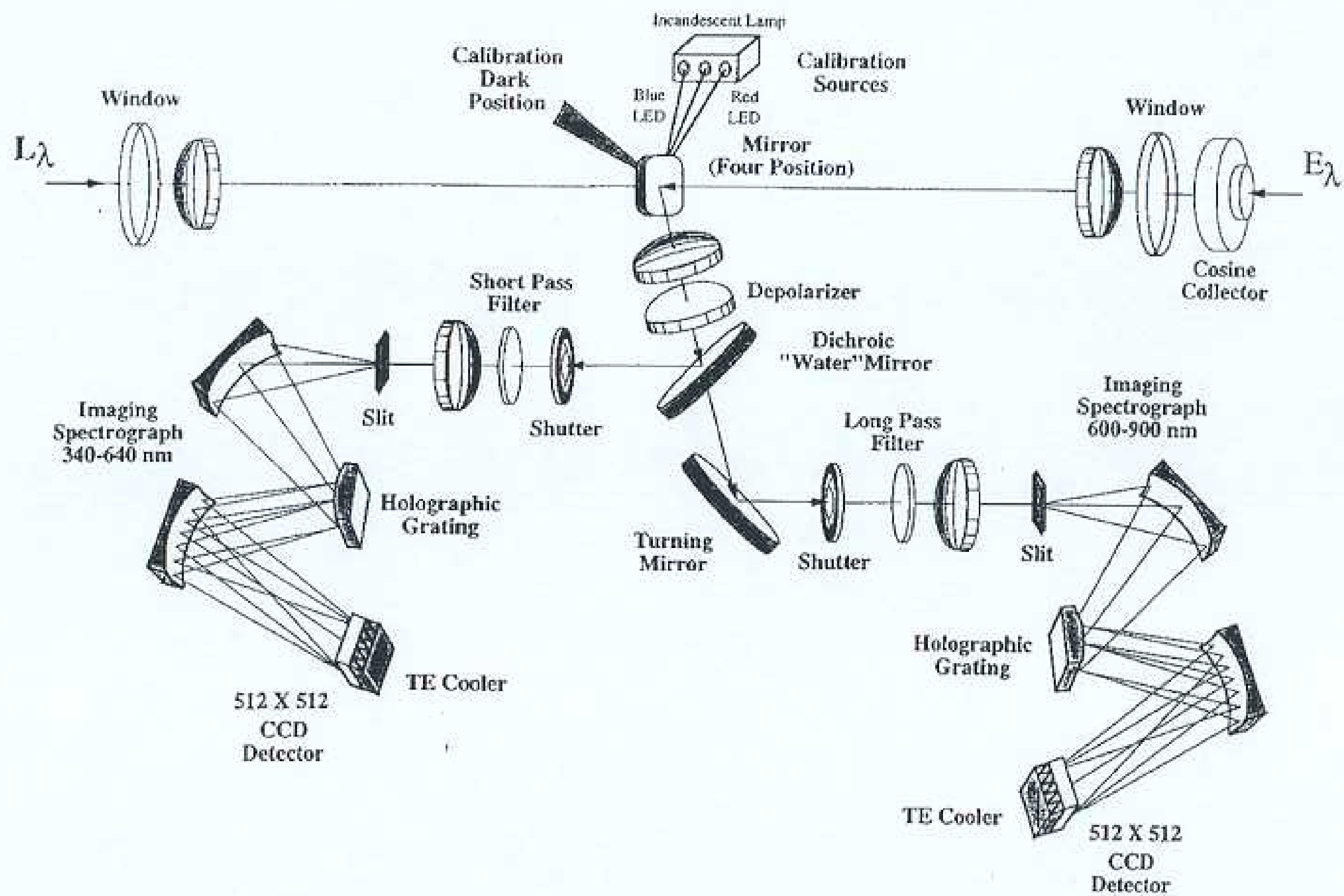


The ratio of the signals is **not** proportional to the ratio of the spectral radiances at λ_0 because the out-of-band contribution is different.

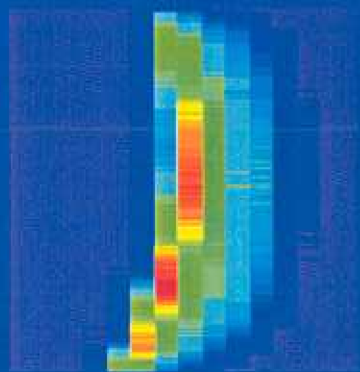
It depends on $L(\lambda)$!

For this example, FR 1 would be incorrect by about 5.7%;
FR 2 by about 0.8 %.

Marine Optical System (MOS)



Spectrographs & Monochromators



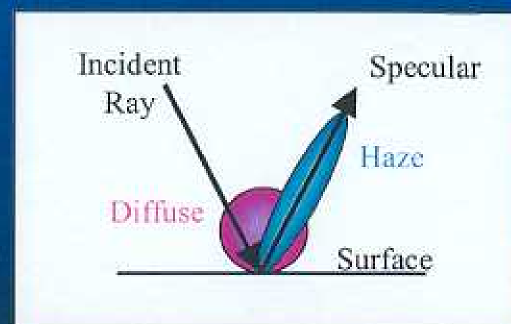
Row (Slit Height)

Column (Wavelength)

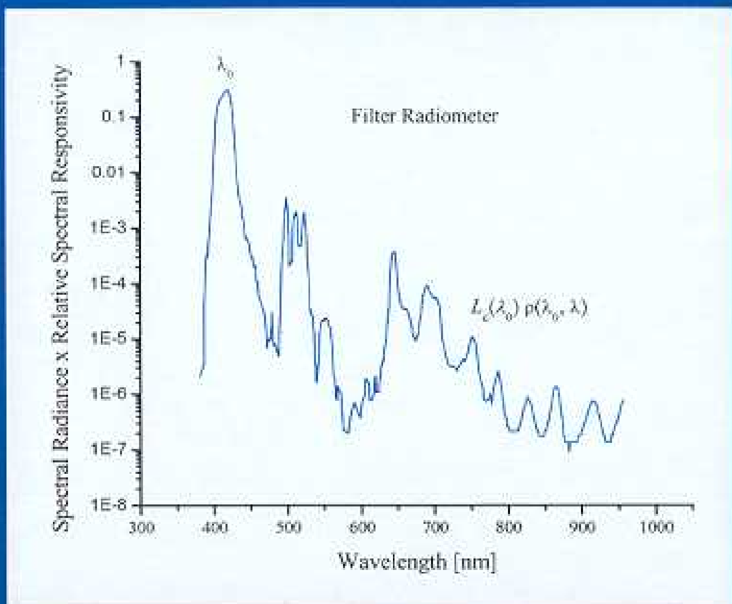
The image appearance in monochromatic light depends on instrument parameters and other effects (the example is not well focused).

Signal = In-band + Out-of-Band

Haze and diffuse scatter contribute to the specular flux. For a grating, this compromises the desired optical interference effect.



Filter Radiometer Measurement Equation



$\rho(\lambda_0, \lambda)$ and $L_c(\lambda)$ are known. Thus $R(\lambda_0)$ and the fraction of signal from the out-of-band ("stray light") can be determined.

$$R(\lambda_0) = \frac{S_c(\lambda_0)}{\int \rho(\lambda_0, \lambda)\, L_c(\lambda)\, d\lambda}$$

The correct $L_u(\lambda)$ solves the equation

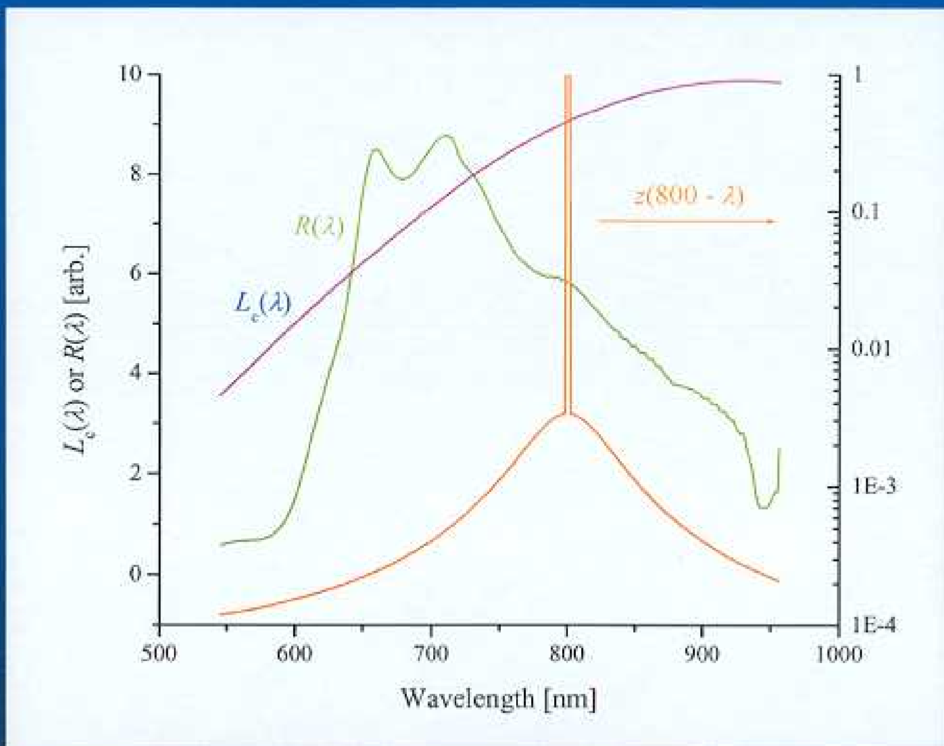
$$S_u(\lambda_0) = R(\lambda_0) \int \rho(\lambda_0, \lambda)\, L_u(\lambda)\, d\lambda$$

Note this requires knowledge of $L_u(\lambda)$ at all wavelengths—a) additional channels and deconvolution or b) delta-function for $\rho(\lambda_0, \lambda)$.

In MOS, the equivalent of $R(\lambda_0)\ \rho(\lambda_0, \lambda)$ is not known, but we have lots of (1024) channels.

Spectrograph Measurement Equation

$$S(\lambda_i) = \int R(\lambda)\, z(\lambda_i - \lambda)\, L(\lambda)\, d\lambda = R(\lambda_i)\, L(\lambda_i)\, \delta\lambda + \sum R(\lambda)\, z(\lambda_i - \lambda)\, L(\lambda)\, \Delta\lambda$$
$$= \text{In band} + \text{Out of band}$$



$z(\lambda_i - \lambda)$ is the slit scatter function.

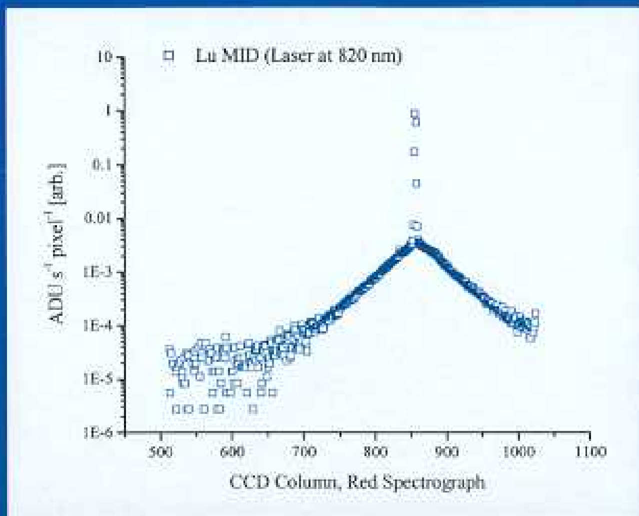
We use an iterative solution to find the system response, followed by an iterative solution for the in-water measurements.

First, we must characterize the optical systems (MOS and MOBY).

Experimental

Tunable Lasers	Tuning Range [nm]
Ti:Sapphire	690 to 900 380 to 430
Dye Laser	580 to 600 610 to 690
Discrete Lasers	Wavelengths [nm]
HeNe's	543, 594, 612, 633
Ar-Ion	458, 488, 514
Diode Lasers	412, 440, 645, 660, 675, 690

Characterization using Tunable Lasers



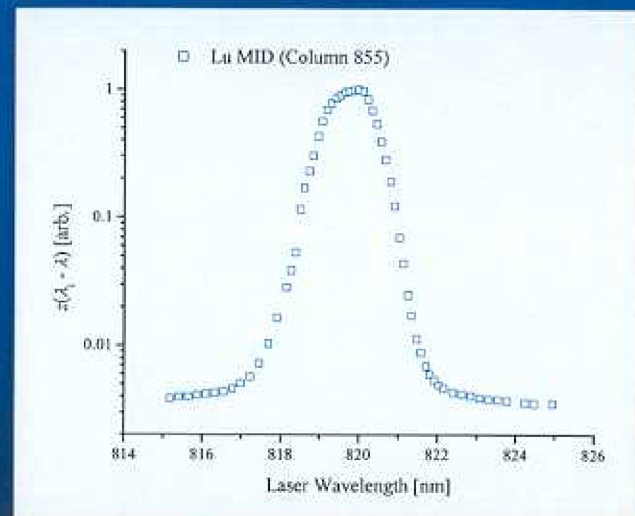
Laser-illuminated integrating sphere:
←←Result at single wavelength

This source is:
Monochromatic (width << $\delta\lambda$);
Uniform, stable, and bright;
Radiance is measured (trap detector).

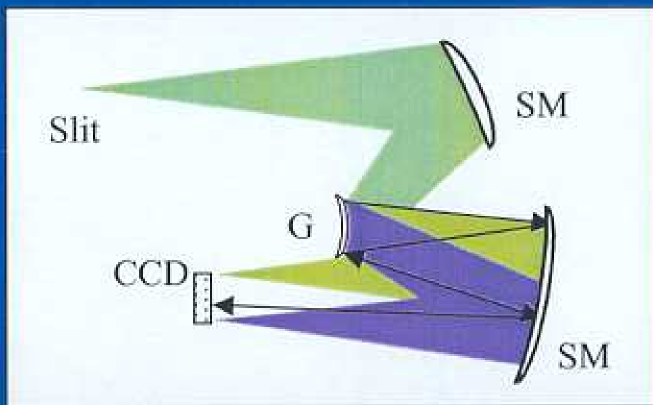
Fine Scans

The laser wavelength is varied by up to 10 nm in steps of about 0.1 nm (60 to 100 measurements). One column will be near the center of this scan.

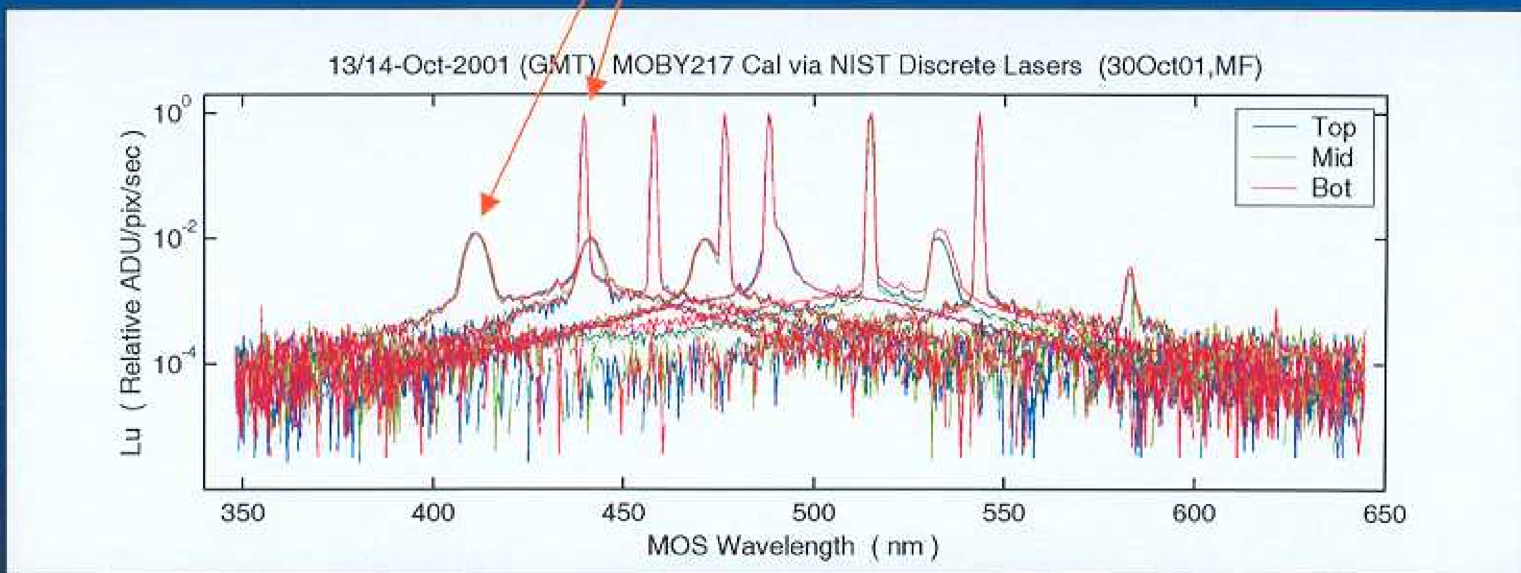
Gives $\delta\lambda$ and a fit to an analytical function for $z(\lambda_i - \lambda)$



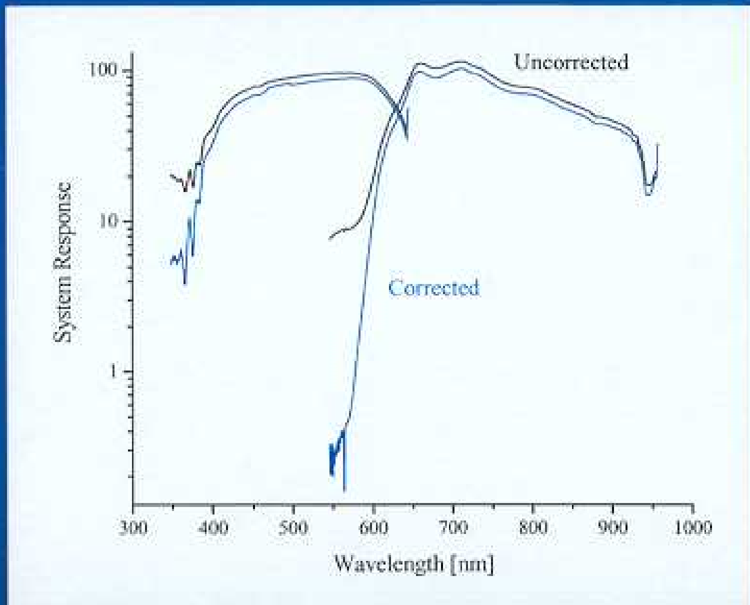
Reflection Peaks



Interreflection of 2nd order causes secondary image (MOS is designed to operate in 1st order).

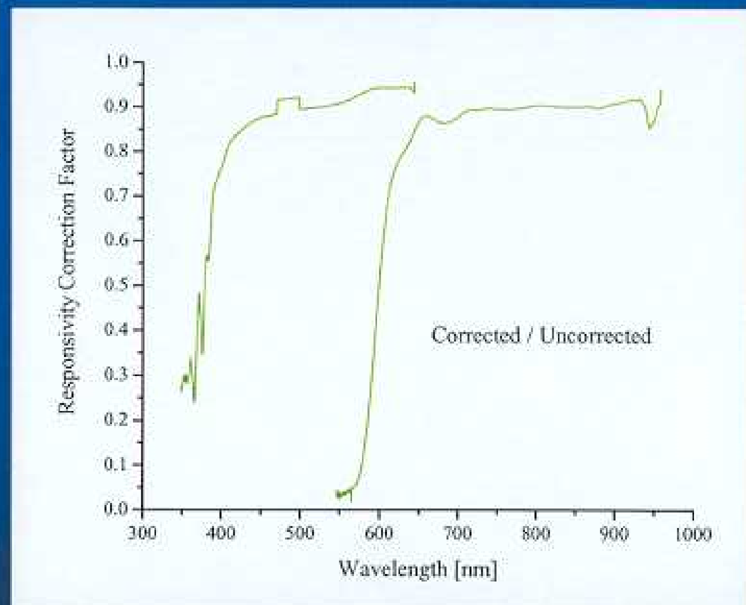


Effect on System Response

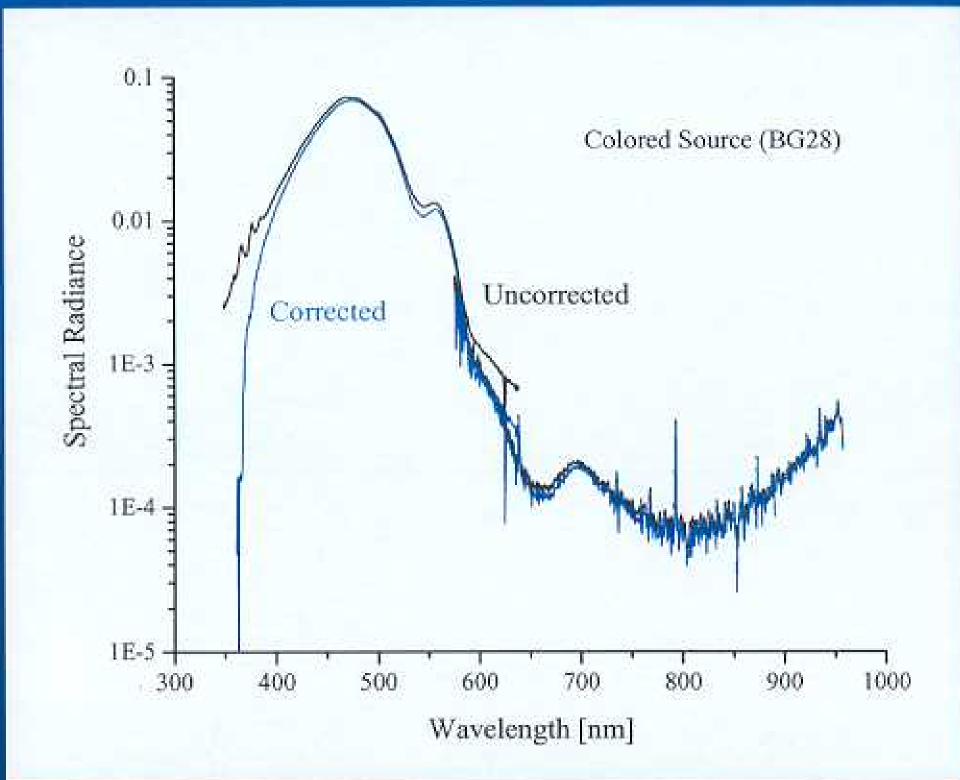


Corrected and Uncorrected System Response

Ratio



Colored Source (CS) for Validation



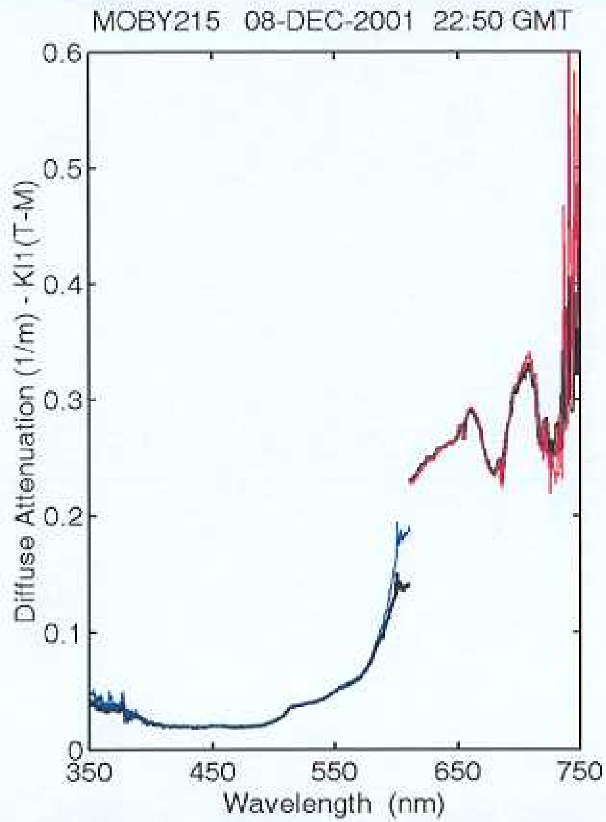
Filtered Sphere Source

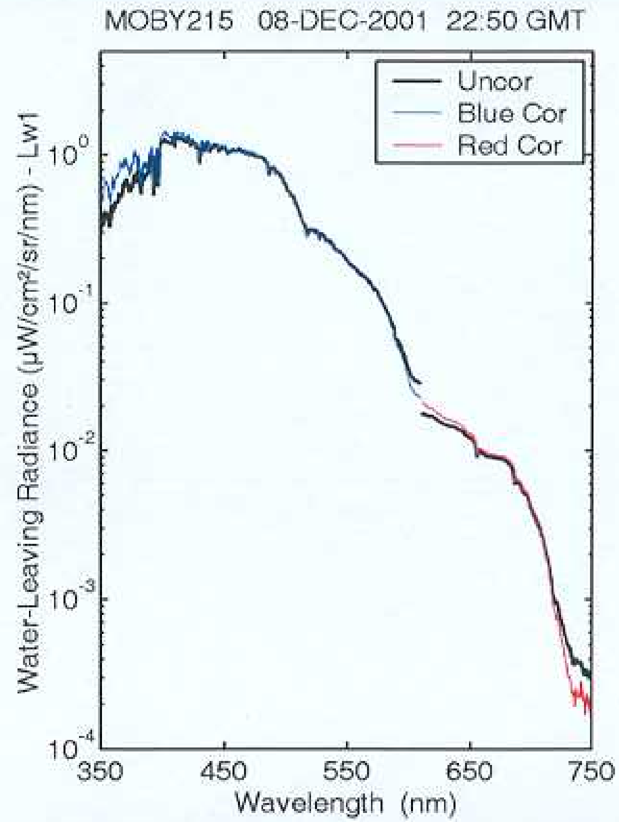
$L(\lambda)$ from measurements with double grating monochromator;

MOBY/MOS measurements of the CS serve as test Lu data sets;

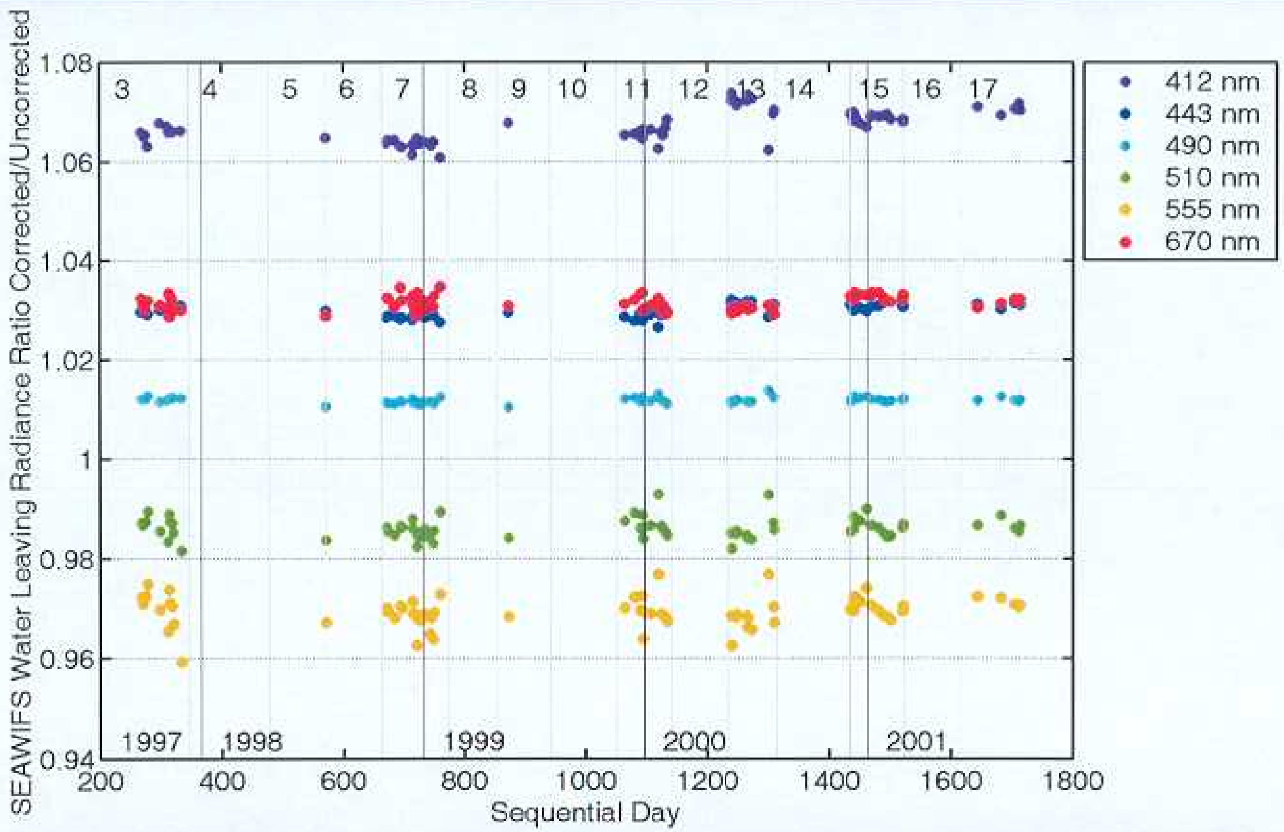
Different glass filters to correspond to Case I or Case II waters; interference filters to test modeling of the reflection peaks.

Result for MOBY215





SeaWiFS Match-Ups



Summary

Correction of 6.8% to –3.0% for SeaWiFS bands

Improved accuracy of MOBY-derived satellite calibration coefficients

Same set of stray light correction parameters (from MOBY217) “works” with all MOBY/MOS205—can go backwards and forwards

Analysis of MOBY/MOS204 and MOS202 (profiler in MOCE cruises) is underway

Thanks to:

MODIS, SeaWiFS, SIMBIOS, NOAA,
NIST, CCG

Measurement Equation

$$S(\lambda_i) = \int R(\lambda)\, z(\lambda_i - \lambda)\, L(\lambda)\, d\lambda$$

$$= R(\lambda_i)\, L(\lambda_i)\, \delta\lambda + \sum R(\lambda)\, z(\lambda_i - \lambda)\, L(\lambda)\, \Delta\lambda$$

$$= \text{In band} + \text{Out of band}$$

$z(\lambda_i - \lambda)$ is the slit scatter function

1. Iterative solution for system response:

If $R_{\mathrm{uc}}(\lambda_i) = \dfrac{S_{\mathrm{c}}(\lambda_i)}{L_{\mathrm{c}}(\lambda_i)\, \delta\lambda}$, then $R^{\upsilon}(\lambda_i) = R_{\mathrm{uc}}(\lambda_i) - \dfrac{\sum R^{\upsilon-1}(\lambda)\, z(\lambda_i - \lambda)\, L_{\mathrm{c}}(\lambda)\, \Delta\lambda}{L_{\mathrm{c}}(\lambda_i)\, \delta\lambda}$

Where $R^{0}(\lambda) = R_{\mathrm{uc}}(\lambda)$ and $L_{\mathrm{c}}(\lambda)$ is the calibration source.

2. Iterative solution for in-water measurements:

If $L_{\mathrm{uc}}(\lambda_i) = \dfrac{S_{\mathrm{w}}(\lambda_i)}{R^{\upsilon}(\lambda_i)}$, then $L^{\eta}(\lambda_i) = L_{\mathrm{uc}}(\lambda_i) - \dfrac{\sum R^{\upsilon}(\lambda)\, z(\lambda_i - \lambda)\, L^{\eta-1}(\lambda)\, \Delta\lambda}{R^{\upsilon}(\lambda_i)\, \delta\lambda}$

Where $L^{0}(\lambda) = L_{\mathrm{uc}}(\lambda)$ and $R^{\upsilon}(\lambda)$ = the corrected system responses.

Appendix 4: History of NOAA/MLML Marine Optical System (MOS) Observations.

Cruise: MOBY-L72, Ship: R/V Ka'imikai-O-Kanaloa, Location: Hawaii (MOS202cfg08)

Station (#	Name)	Date (GMT)	Time (GMT)	Latitude (+North)	Longitude (+East)	Depths (dbar)
01	MOBY Mooring I	25-Sep-2001	20:45	20.8	-157.2	NO MOS
02	10 nm SW of MOBY	26-Sep-2001	21:15	20.727	-157.367	1,6,9

Cruise: MOCE-9, Ship: R/V Klaus Wyrtki, Location: Hawaii (MOS202cfg08)

Station (#	Name)	Date (GMT)	Time (GMT)	Latitude (+North)	Longitude (+East)	Depths (dbar)
01	S. Shore Oahu	29-Nov-2001	21:15	21.248	-157.920	1,3,6
02	W. Side Oahu I	03-Dec-2001	20:56	21.330	-158.238	1,4,9
03	W. Side Oahu II	06-Dec-2001	21:22	21.478	-158.332	1,3,6
04	W. Side Oahu III	08-Dec-2001	21:09	21.484	-158.417	NO MOS
05	W. Side Oahu IV	09-Dec-2001	21:51	21.480	-158.350	1,3,5,9
06	W. Side Oahu V	10-Dec-2001	20:56	21.41	-158.347	1,3,5
07	W. Side Oahu VI	11-Dec-2001	21:39	21.	-158.	NO MOS